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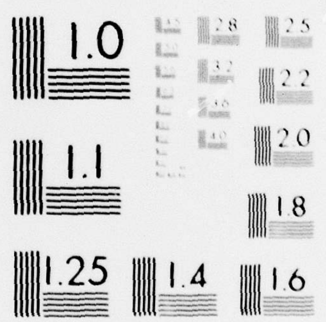

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A GUIDE TO U.S. NAVY COMMAND, CONTROL, AND COMMUNICATIONS

Prepared by
Santa Fe Corporation

1 July 1979
for
Command Control and Communications
Directorate (Code 08)

Final Report – May 1978 to May 1979

NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CALIFORNIA 92152

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AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

SL GUILLE, CAPT, USN
Commander

HL BLOOD
Technical Director

The Guide to U.S. Navy Command, Control, and Communications was prepared by Santa Fe Corporation under the supervision of the Director, Command Control and Communications Directorate (Code 08), with funds provided by the Naval Ocean Systems Center. It is intended to serve as a broad introduction to the field of U.S. Navy C^3.

Released under authority of
RH DuBois, Head
Command Control and Communications Directorate
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Naval command, control, and communications (C^3) is examined from early applications through the development of U.S. Navy C^3 to date. Current national and Navy C^3 systems and organizations are described. The role of C^3 personnel is explained briefly. Finally, significant overall trends in U.S. Navy C^3 technology and organization are identified.

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FOREWORD

Command, Control, and Communications (C^3) is a relatively recent combination of terms describing functions that have been part of military operations for thousands of years. The combination is convenient because the term C^3 refers to essential and related operations that are vital for the success of modern military forces, and because C^3 operations have in recent times come to depend so heavily upon one technical field -- electronics.

Variations in technology, concepts, and relationships to other military functions and operations exist in the C^3 area. Such variations, however, should not distract the reader of this handbook from the basic concept of the term C^3: to indicate a related set of functions essential to the employment of men, weapons, sensors, and platforms in modern warfare.

Naval C^3 is receiving increasing attention as the need intensifies for the effective control of widely dispersed forces -- including air, surface, submarine, satellite, and land -- in coordinated or at least related operations. The rapid proliferation of precision-guided weapons, the availability of "tactical" and "strategic" nuclear weapons, the technological improvements of Soviet and certain Third World naval forces, the great variety of sensor systems in existence, and many other factors increase the need for real-time, secure, redundant, and effective naval C^3.

The purpose of this handbook is to provide, at the unclassified level, a broad overview of naval C^3 development, trends, requirements, and capabilities based on fundamental principles -- to serve as a first textbook, or "primer," on U.S. Navy C^3.

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GLOSSARY

AAW Anti-Air Warfare

ADCOM Aerospace Defense Command (Specified Command)

ADP Automatic Data Processing

ADT Automatic Detection and Tracking

AEGIS Highly automated anti-air weapon system for the DDG-47 class missile destroyers

AGC Amphibious command ship (now LCC)

AGMR Major communications relay ship

Analog In the form of numbers represented by directly measurable quantities, such as voltages in an electrical analog computer, or the rotations in a mechanical computer

ANMCC Alternate National Military Command Center

ASW Anti-Submarine Warfare

ASWCCCS ASW Centers Command Control System

ATDS Airborne Tactical Data System

AUTODIN Automatic Digital Network of the U.S. Department of Defense

AUTOSEVOCOM Automatic Secure Voice Communications Network of the U.S. Department of Defense

AUTOVON Automatic Voice Network of the Department of Defense

Battle Force A naval task force based on aircraft carriers

C^3 Command, Control, and Communications

C^4 Command, Control, Communications, and Computers

C^3I Communications, Command, Control, and Intelligence

C^3 SITE C^3 Systems Integration Test and Evaluation facility

CDS Combat Direction System

Channel Path for one-way message transmission

CIC Combat Information Center

CINC Commander-in-Chief

CINCEUR Commander-in-Chief, U.S. Forces Europe

CINCLANT Commander-in-Chief, U.S. Atlantic Command

CINCLANTFLT Commander-in-Chief, U.S. Atlantic Fleet

CINCPAC Commander-in-Chief, U.S. Pacific Command

CINCPACFLT Commander-in-Chief, U.S. Pacific Fleet

CINCUS Commander-in-Chief, United States Fleet (position no longer in existence)

CINCUSNAVEUR Commander-in-Chief, U.S. Naval Forces Europe

Circuit Complete electrical path providing one or two-way communications between two points with associated go and return channels

CNET Chief of Naval Education and Training

CNM Chief of Naval Material

CNO Chief of Naval Operations

COMSAT Communications Satellite Corporation

COMSECONDFLT Commander, U.S. Second Fleet (Atlantic)

COMSEVENTHFLT Commander, U.S. Seventh Fleet (Western Pacific)

COMSIXTHFLT Commander, U.S. Sixth Fleet (Mediterranean)

COMTHIRDFLT Commander, U.S. Third Fleet (Eastern Pacific)

CONUS Continental United States

CV-IC Aircraft Carrier Intelligence Center

CV-TSC Aircraft Carrier Tactical Support Center

DARPA Defense Advanced Research Projects Agency

Data Rate The amount of data that a given communications path can carry in a given period of time

DCA Defense Communications Agency

DCS Defense Communications System

DF Direction Finding

Digital In the form of digits; (e.g., a digital computer operates with numbers expressed directly as digits)

Display Device that provides information in visual form (e.g., a cathode ray tube)

DNA Defense Nuclear Agency

DoD Department of Defense

DS Data Systems Technician rating

DSCS Defense Satellite Communication System

Duplex Two-way communication over a single link, either alternately (Half Duplex) or simultaneously (Full Duplex)

ECCM Electronic Counter-Countermeasures

ECHO I, II First U.S. communications satellites

ECM Electronic Countermeasures to prevent effective enemy use of electromagnetic spectrum

EHF Extremely High Frequency

ELF Extremely Low Frequency

EO Electro-Optical

ESM Electronic Support Measures

ET Electronics Technician rating

EUCOM European Command

FCC Fleet Command Center

FLTSATCOM Fleet Satellite Communications System

FOSIC Fleet Ocean Surveillance Information Center

FOSIF Fleet Ocean Surveillance Information Facility

Frequency Number of complete wave cycles that pass a given point in a given time

GAPFILLER Satellite communication facilities temporarily leased by the Navy

Giga Prefix denoting one billion

Ground Wave Radio signal that tends to remain close to the surface, following the curvature of the earth

Group Commander Administrative subordinate of a naval type commander

HF High Frequency

HF/DF High Frequency/Direction Finding

Hz Hertz; cycles per second

Kilo Prefix denoting one thousand

JCS Joint Chiefs of Staff

JTIDS Joint Tactical Information Distribution System

LSI Large-Scale Integration

LANTCOM Atlantic Command

LCC Amphibious command ship (formerly AGC)

LF Low Frequency

Line-of-Sight Traveling in a straight line from the source

Link A communication path between two points in which the signal takes the same form at both ends (e.g., radio link)

Link 4A NTDS one-way tactical aircraft link

Link 11 NTDS two-way encrypted data link

Link 14 NTDS encrypted data link to non-NTDS ships

LORAN Long-Range Electronic Navigation System

LOS Line-of-Sight

LSH Landing Ship Headquarters (British)

MAC Military Airlift Command (a Specified Command)

MACCS Marine Air Command and Control System

MEECN Minimum Essential Emergency Communications Network

Mega Prefix denoting million

Multiplex Transmission of two or more data streams in a single channel, either simultaneously or alternately

NANCY Shipboard signaling system using the infrared spectrum

NASA National Aeronautics and Space Administration

NATO North Atlantic Treaty Organization

NAVAIR Naval Air Systems Command

Naval Component Commander The commander of U.S. naval forces assigned to a Unified Command

NAVCAMS Naval Communications Area Master Station

NAVCOMMSTA Naval Communications Station

NAVELEX Naval Electronic Systems Command

NAVMAT Naval Material Command

NAVSEA Naval Sea Systems Command

NAVSEC Naval Ship Engineering Center

NAVSTAR GPS NAVSTAR Global Positioning System; precise navigation system using satellites

NCA National Command Authority

NCCS Navy Command and Control System

NCC Naval Command Center (originally the Naval Operations Center, later the Naval Command Support Center); the C^3 node supporting the CNO and his staff

NEACP National Emergency Airborne Command Post

NECPA National Emergency Command Post Afloat

Network An interconnected or interrelated group of nodes for communication or data processing

NFC Numbered Fleet Commander (e.g., COMSIXTHFLT)

NMC Naval Material Command

NMCC National Military Command Center

NMCS National Military Command System

Node End point of any branch in a network, or a junction common to two or more branches of a network

North Atlantic Council The civilian consultative body that sets NATO policy

NOSC Naval Ocean Systems Center

NOSIC Naval Ocean Surveillance Information Center

NRL Naval Research Laboratory

NSA / CSS National Security Agency / Central Security Service

NSC National Security Council

NTC Naval Telecommunications Command

NTDS Naval Tactical Data System

NTS Naval Telecommunications System

OIC Operational Intelligence Center (British)

OP-094 Director, Command and Control and Communications Programs, Office of the Chief of Naval Operations

OP-098 Director, Research, Development, Test and Evaluation, Office of the Chief of Naval Operations

OP-099 Director, Naval Education and Training, Office of the Chief of Naval Operations

OPCON Center Operational Control Center

OPNAV Office of the Chief of Naval Operations

OS Operations Specialist rating

OSD Office of the Secretary of Defense

OSIS Ocean Surveillance Information System

OTC Officer in Tactical Command

OTH Over-The-Horizon

PACOM Pacific Command

PME-108 Project Manager, Command, Control and Communications Systems, Naval Electronic Systems Command

PPI Plan Position Indicator

RDT&E Research, Development, Test, and Evaluation

Real-Time Timeframe sufficiently close to that of a related physical process so that the results of computation or decision-making can help to guide that process

REDCOM Readiness Command

RF Radio Frequency

RM Radioman rating

RTT Radio Teletype

SAC Strategic Air Command

SACEUR Supreme Allied Commander Europe

SACLANT Supreme Allied Commander Atlantic

SANGUINE Early code name for SEAFARER strategic submarine communications program

SEAFARER ELF broadcast system developed for the strategic submarine force

SECDEF Secretary of Defense

SECNAV Secretary of the Navy

SHF Super High Frequency

Simplex One-way-only communication (sometimes used to refer to two-way alternate communication)

Sky Wave A radio wave reflected back to earth from the atmosphere, particularly the Ionosphere

SM Signalman rating

SOSUS Sound Surveillance System

SOUTHCOM Southern Command

Specified Command A major U.S. military command organized around a specific function operating primarily from the continental U.S. (SAC, MAC, ADCOM)

SSES Ship Signal Exploitation Space

SYNCOM First satellites to demonstrate geosynchronous orbit

TACAMO Navy strategic communications system employing EC-130G/Q relay aircraft

TAC/TADS Tactical Air Control/ Tactical Air Defense System

Task Force Component of a fleet organized by the numbered fleet commander or higher authority to accomplish a specific task or tasks

Task Group Component of a naval task force organized by the task force commander or higher authority

TELSTAR First commercial relay satellite using solar power

TF Task Force

TFCC Tactical Flag Command Center

TG Task Group

TRI/TAC Tri-Service Tactical Communications Program

TSC Tactical Support Center

Type Commander Navy administrative command with responsibility for ships or aircraft of a given type

UHF Ultra-High Frequency

Unified Command A major U.S. military command responsible for a given geographic area outside the continental U.S. and normally including elements of several services (e.g., PACOM, LANTCOM, EUCOM, SOUTHCOM)

VHF Very High Frequency

VLF Very Low Frequency

VP-TSC Patrol Aircraft Tactical Support Center

Wavelength Distance in the line of advance of an electromagnetic wave from any one point to the next point of the same phase, i.e., the physical length of one complete oscillation

Wireless Radio (archaic)

WT Wireless Telegraph (archaic)

WWMCCS World Wide Military Command and Control System

1
PERSPECTIVE

Command, control, and communications are key functions that provide for the direction of modern military forces. The terms have been combined in recent years as a matter of convenience -- and popularly expressed as C^3 ("C-cubed") -- to describe essential functions which military decision-makers carry out in order to employ the forces under their command.

Command may be defined as "the will of a commander expressed for the purpose of bringing about a particular action."* Control may be considered as the regulation and coordination of forces. In one sense, "control" is an extension of "command," providing for real-time monitoring of performance and status, and implying the capability to modify directions. Communications is "a method or means of conveying information....from one person or place to another,"** a classic military function. The marriage of these three terms probably resulted from a developing need to better coordinate widely separated military forces and a general similarity of the hardware -- most of which involves electronics -- required to support these functions.

As an aggregated naval function, command, control, and communications touches on a number of related functions such as intelligence, surveillance, navigation, administration, and logistics. All of these functions provide information or "input" that must be considered in performing the integrated C^3 function, since all of them deal with some aspect of the general military situation. A C^3 system must provide the means whereby military decision-makers have access to the information that these other functions provide.

To understand the nature of C^3, it is helpful to examine each of its three components in greater detail.

COMMAND

Command has two principal elements: organization and direction. The first of these is structural, and is most commonly expressed in military terms by the notion of a "chain of command" made up of superiors and subordinates. In practical application, the functioning of any organization is apt not to follow these neat relationships to the letter. Thus, any attempt at describing a purely hierarchical structure of superiors and subordinates invariably oversimplifies the relationships.

Traditional command arrangements tend to allow considerable latitude for consultation, conferencing, and other complex interactions. But even these arrangements tend to lock decision-makers into overly rigid (usually automatic) systems that isolate them from vital information, or that provide them with more raw data than they can possibly use. The likelihood of this occurring has increased with modern information handling systems, which operate at greater speeds and deal with much more raw data. Therefore, one of the main goals of the detailed analysis and planning associated with modern command is to give each level of command specifically the information it requires.

It is not always possible, however, to anticipate all of the decision-makers' needs, much less meet them in a timely fashion. Given the propensity of automated data systems -- whose judgment is only as good as their programs -- to provide too much raw data, the emphasis in recent years has been on restricting the information with which each decision-maker must deal. Despite the human desire to exploit all information handling systems to the fullest, systems planners have come to realize that C^3 remains very much a human activity, and that commanders want to see on their displays only information that they can use for the next few decisions they will be called upon to make.

**Joint Chiefs of Staff*, Dictionary of Military and Associated Terms, *JCS Pub. 1, p 74, Department of Defense, 1973*

**Ibid, *p 85*

The second element of command, directing the employment of military force, is functional rather than structural. It involves the execution of decision through the issuance of orders which are communicated to the force. The modern command function does not differ from earlier forms in terms of the commander's distance from the forces which he is directing. Roman emperors issued orders from Rome to naval squadrons in the Black Sea. The British Admiralty during the age of sail routinely commanded the movements of squadrons in the Pacific or off the coast of India. The crucial difference between command now and in earlier periods lies in the speed with which a decision-maker can establish contact with distant forces. This change relates directly to the second component of C^3: control.

CONTROL

In the age of sail, and in many cases until much more recently, effective control remained the exclusive function of the decision-maker at the scene of action. The distant commander could tell the executing officer -- the man who carried out his orders -- what he wanted done, and even how to do it. However, he had no way of monitoring the resulting actions until long after they had taken place. The distant commander lacked the essential element of control: real-time communications and data handling.

"Real-time" does not necessarily mean immediate, although increases in weapon delivery speeds tend to push control systems ever closer to the goal of instantaneous response. "Real-time" does imply the ability to monitor a developing tactical situation, to make appropriate decisions, and to issue orders in a timeframe that will permit the commander to have the desired effect on the outcome. The aspect of the post-World War II technological revolution that has had the greatest consequences for modern C^3 is the extension of the real-time control function to commanders far removed from the scene of action.

Figure 1-1. The commanding officer of a Navy ship supervises an underway replenishment operation. Despite revolutionary advances in command systems, the essence of naval command continues to be cooperation between superiors and subordinates to achieve common goals.

Due to improvements in wide area surveillance, distant decision-makers may also have better access than local commanders to useful information on the developing local situation. The distant control that technological advances make possible can be useful in an operating environment where nuclear weapons require greater dispersion of forces, or where the increasing speed of delivery systems leaves the local commander too little time for making decisions once his own limited surveillance perceives the threat. But distant control of tactical forces also has drawbacks. One of the important challenges facing today's C^3 specialists is to identify and establish the proper limits of C^3.

Whenever commanders in a chain of command are in close communication with each other, there may be a tendency for the superior to assume the command responsibilities of his subordinate. Such relationships involve a delicate balancing and ordering of each officer's functions and spheres of authority. Advanced C^3 systems have, to some extent, placed not only the task group commander, but the task force, fleet, and even national commander "in the same ship." In a given crisis situation, the captain of a destroyer could conceivably find himself taking "rudder orders" from the President of the United States.

This may, in fact, be necessary for certain crises in which only high-level command authority can provide the required degree of political direction. Most C^3 analysts agree that higher authorities should have the option to use this command and control capability, but that they should use it only when absolutely essential. No matter how sophisticated and extensive the systems supporting a distant decision-maker, the overall C^3 structure, by its very nature, can support only a limited amount of distant tactical control.

A local commander can tolerate no more than a given level of intervention without forfeiting his own important contribution to tactical decision-making. Similarly, a higher-level decision-maker cannot make

Figure 1-2. The "situation room" of the specially configured flagship Northampton *(CLC-1) in 1961, just prior to her designation as the first National Emergency Command Post Afloat (NECPA). Advances in communications and information handling have greatly extended the area under the direct control of a naval commander.*

Figure 1-3. Bridge personnel of the carrier Nimitz *(CVN-68) man sound-powered telephones as the ship enters port. Communications are both a basic human function and an element of modern* C^3.

numerous tactical decisions without degrading his ability to deal with the overall situation. It has been suggested that a distant commander simply refrain from intervening in local situations. This is not always desirable, however, since his C^3 systems sometimes give him better information than the local commander. Restraint on the part of the distant commander must go hand-in-hand with improvements in the flow of pertinent information throughout the command structure. High-speed data exchange and information-sharing must give the local commander the information he needs automatically, minimizing the need for intervention from higher command levels. Fortunately, systems now under development promise to supply the local commander with precisely those parts of the "big picture" that he will need in order to make intelligent, timely local decisions.

COMMUNICATIONS

Communications, even more than command and control, are a natural human activity. Men are very much at ease with communications, adapting quickly to their latest technological manifestation. Given the availability of a communications link -- i.e., a connection between a transmitter and a receiver -- men will use that link. The very existence of a new network of communications links creates a new demand, just as the opening of a new highway system breeds traffic by encouraging people to structure their activities around its use. The incredible growth of citizen band radio in recent years is an example of this phenomenon.

The tendency to make the greatest use of available communications is especially significant in the light of recent efforts toward the overall integration of C^3 systems. Planners must keep in mind the many ways in which communications nets that are adequate today can become glutted tomorrow. One of the principal advantages of the systems architecture approach is that it considers the effects that each individual development will have on overall requirements. A total systems approach enables planners to limit the amount of communications by carefully structuring the relationship between communications, on the one hand, and command and control, on the other.

One way to limit the communications burden of C^3 is to delineate as clearly as possible those communications that are part of C^3 and those that are not. C^3 deals primarily with operations; therefore, administrative messages, except for those that have a direct impact on operations, can be considered to lie outside the scope of the C^3 function. For example, a request for a spare part that will enable a ship to continue performing its mission has a sufficiently high priority in the operational sphere to be within the scope of naval C^3. Routine reports do not. Therefore, a C^3 system should simply provide communications access to the appropriate administrative activity.

Characteristic of the C^3 functions is a certain amount of overlap between the communications function and command and control. Even the most primitive communications called for a certain amount of data handling and decision-making in the employment of the communications links themselves. Command and control for naval communications is increasingly provided by computers and digital displays. The complexity of data exchange, in particular, calls for the high speed and capacity of automatic data processing. Not only has the number of major communications nets increased, along with the number of smaller nets within the larger framework, but the high rate at which the data and information flow through these nets increasingly necessitates rapid and minute net control, including precise divisions of time among users, and very high-speed switching from one channel to another.

Just as command and control requires good communications, so communications require capable command and control. Coordinating a worldwide communications net is itself a major undertaking, necessitating sophisticated command and control installations merely to oversee and direct the flow of traffic. Even the internal communications of a C^3 node, or installation, call for special command and control equipment to handle the large volume of high-speed message traffic.

CHANGING NATURE OF C^3

If naval commanders and their subordinates have carried out the basic C^3 functions for as long as navies have existed, why has so much interest been generated in this field in recent years? One reason is that C^3 has more impact today than in the past. This is true not only in military applications, but in the

numerous civilian activities that now call for precise decision-making and rapid action. The techniques of modern C^3 are finding applications in air traffic control, in the control of merchant shipping, and in a host of other areas. Nevertheless, military organizations, including the U.S. Navy, remain the primary users of C^3 technology. The speed and capability of advanced weapons and sensors ensure that this will continue to be the case.

The impact of C^3 has increased largely because electronic systems have replaced earlier mechanical systems in a great many areas. In the U.S. Navy, for example, higher levels of technology have led to spectacular increases in the relative amount of total resources allocated to electronics. The percentage of total combat system weight taken up by electronic sensors and C^3 equipment in U.S. surface combatants has risen by at least a factor of three since World War II. The highly automated combat system of the new DDG-47 Aegis destroyer will dedicate an even greater percentage of its total weight to electronics.

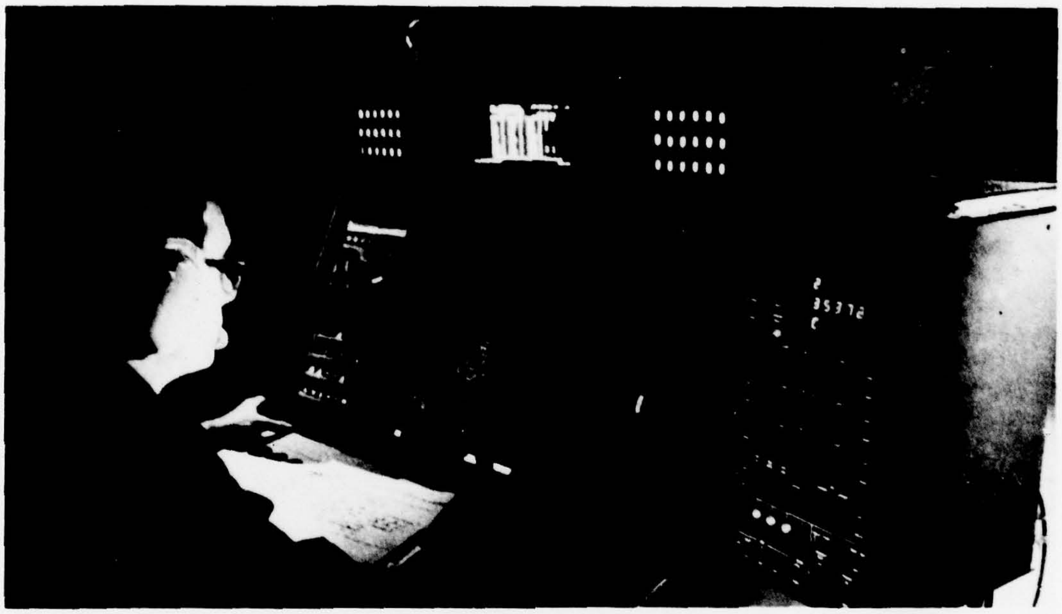

Figure 1-4. An officer demonstrates the coordination of air defense activity at a test site for the Navy's advanced Aegis Weapon System. The speed and precision of modern naval warfare call for matching improvements in C^3 equipment and facilities.

Advanced electronics have enabled fewer, "smarter" weapon and sensor systems to replace the more numerous but less capable systems of the past. Whereas an anti-aircraft ship of World War II might fire thousands of short-range shells at a relatively slow-moving enemy aircraft with little or no effect, a modern Aegis ship will be able to achieve much better results with a few, long-range missiles, all fired within seconds of the first warning. The speed and precision of modern combat systems call for matching improvements in the C^3 function. Now that the outcome of a major naval battle can be determined in seconds with a handful of well placed rounds, the advantage that will accrue to the side with the most effective C^3 is hard to overestimate. The post-war electronic revolution has led to concomitant improvements in communications, information handling, and displays and decision aids, enabling C^3 systems to carry out their functions in today's combat environment.

The greatest C^3 advances have come about as a result of automation which, in turn, requires detailed analysis of the tasks that electronic systems are expected to perform. This is the reason that C^3 functions

have been subjected to much more analysis since World War II than ever before. Unlike automated systems, human decision-makers and C^3 operators can analyze their own behavior and seek ways to improve their own performance. Because this human tendency is innate, and frequently intuitive, it does not call for an especially high degree of functional definition, or a particularly wide-ranging analysis of the tasks being performed. In contrast, automated C^3 systems -- even flexible, adaptive systems made possible by high-speed data processing -- are much less subtle. Their inherent inability to learn and to improve their own perfomance calls for much more detailed planning than the trial-and-error development of the past.

TOTAL SYSTEM APPROACH

As recently as World War II, the systems and procedures used to direct naval forces at sea were still largely the product of many years of collective trial-and-error. Naval planners did not have to give much thought to the logical structure that governed the actions of commanders at sea. It was enough for the commander to do his duty in the accustomed manner. The analysis of C^3, to the extent that it took place, concentrated on limited areas such as communications procedures, which might, from time to time, need adjustment. The slow pace of technological development compared to the present day required little more.

World War II was the watershed between traditional and modern approaches to command, control, and communications. Steadily, the pace of technological change and the tempo of combat gathered speed and began to outpace the capabilities of the older C^3 systems. Despite its ability to adapt and learn, the human mind remained too limited in speed and processing capability to meet all the demands of the post-war C^3 environment. The electronic technology explosion provided electronic systems to take over many C^3 tasks, and it became necessary to analyze each of those tasks with much greater care.

Cybernetics, the post-World War II science of automatic data processing and control, provided many of the necessary analytical tools. In order to apply the capabilities of automatic data processing to an organized human function like C^3, it was necessary first to model the human tasks involved, then to find ways in which an electrical process could be made to reproduce the essential features of each task. Provided the analyses were sufficiently detailed and precise, automatic data processing could then help to make up for the speed and capacity deficiencies of human operators and decision-makers.

The early, piecemeal application of systems analysis to specific segments of the overall Navy command, control, and communications functions left much to be desired. Only those areas most in need of improvement received detailed examination. Analysis and system design activities in closely related areas often proceeded with little or no correlation between activities. The inevitable product of this application of systems analysis was a patchwork C^3 structure composed of "vertically oriented" components with poor "horizontal" interface between one component and another.

More recently, the emphasis has shifted to the horizontal integration of C^3 systems. This calls for a systematic approach to design criteria covering the full range of U.S. Navy command, control, and communications. The "total system approach" is the cornerstone of contemporary system architecture. System architecture design requires the breakdown of C^3 into discrete elements and concentrates on the extremely complex relationship among all the elements within the overall function of command, control, and communications.

Because it considers the overall context, the system architecture approach provides for rapid adjustment to technological change, thus providing a more rational framework in which to make decisions about applying new C^3-related technologies and adjusting to new military demands. This ability to deal intelligently with rapid change is a principal benefit of modern system architecture.

FUTURE IMPORTANCE OF C^3

The increased speed and scope of modern warfare places more emphasis on the "military nervous system" with each passing year. Quick reaction has become a requirement for effectiveness. Moreover, the

proliferation of nuclear weapons and highly accurate conventional weapons, and the serious consequences of their possible use, have redoubled the demand for precisely measured military responses to fast-moving crisis situations.

These incentives to seek improvements in the U.S. Navy's C^3 capabilities are further reinforced by the economic advantages offered by the promise of greater force efficiency. Improvements in C^3 can have a "force-multiplier" effect, enabling fewer units to achieve military effectiveness equivalent to a much larger force. In an era of budget constraints and force reductions, the U.S. Navy cannot afford to pass up the opportunity to make the best possible use of available forces. Continued improvements in C^3 will ensure that no hidden reservoir of potential military strength remains untapped in the future.

2
NAVAL C^3 PRIOR TO WORLD WAR II

AGE OF SAIL

Command, Control, and Communications is a modern term, but the essentials of naval C^3 were already understood by the 1700s, when the sailing fleets of England and France struggled for maritime supremacy. By that time, several navies had large headquarters staffs and trained officer corps, governed by formal regulations and doctrines. These command instruments achieved an unprecedented degree of responsiveness and flexibility. The English and French navies could not only assemble and escort large convoys from distant continents, but could amend their sailing orders by dispatches to ports of call along their routes.

More responsive command naturally gave rise to abuses. As Alfred Thayer Mahan commented in *The Influence of Sea Power Upon History,* his famous study of eighteenth century naval strategy, "To interfere....with the commander in the field or afloat is one of the most common temptations to the government in the cabinet, and is generally disastrous."* During one conflict with England, the French Minister of Marine sent specific operational instructions to a naval commander near India. Since these orders could not possibly take the local situation into account, the French theater commander had no choice but to disobey them, and, fortunately for him, won a limited victory over his British opponent.

A high degree of naval organization gave national authorities an unprecedented ability to command naval forces, but primitive communications severely limited the long-distance control of those forces. For real-time feedback and continuous contact with executing officers, the eighteenth century decision-maker had to be within line of sight of the engagement.

The most important communications medium for controlling a sailing fleet was the flag signal. Each executing officer in a "line of battle" read the commander's signals and acknowledged them by repetition. Executing officers who could not make out the commander's signal flags could read the acknowledgement signals of nearer ships. Flag signals depended on good visibility and had a relatively low data rate, but they were quite adequate for slow-paced, daytime maneuvering of sailing fleets. Cannon smoke, darkness, and the destruction of signal yards were the chief impediments to flag communications during naval battles of this period.

Cannon fire itself could serve as an agreed-upon signal under special circumstances such as naval blockade, when guard ships might have to report an enemy sortie at night or in poor visibility. Lights were also employed at night, but primarily for station-keeping at sea. Primitive flame lanterns made light signalling difficult because the flame itself was hard to control.

Since flag signalling permitted little feedback from other ships, the eighteenth century fleet commander exercised control on the basis of personal observations and the reports of lookouts in the foretop. Finding the best location for the fleet commander was as much a problem then as it is today. The battle line usually consisted of three divisions: van, center, and rear. Each division had its own commander, with the commander-in-chief of the entire fleet normally being the commander of the center. A few officers, like Nelson, preferred to control the fleet from the van, where the example of the commander's ship supplemented his signals, reducing misunderstandings. The weakness of this approach was that it often exposed the chief decision-maker to the greatest danger and frequently cut him off from contact with subordinates at the very beginning of an engagement. The French Navy sometimes went to the opposite extreme to keep the decision-maker out of action but in contact with subordinates, placing him in a frigate behind the battle line. The problem with this solution was that the fleet commander sometimes lost track of the distant enemy.

**Mahan, A.T.,* The Influence of Sea Power Upon History, 1660-1783, *First American Century Series Edition, p 94, Hill and Wang, 1957*

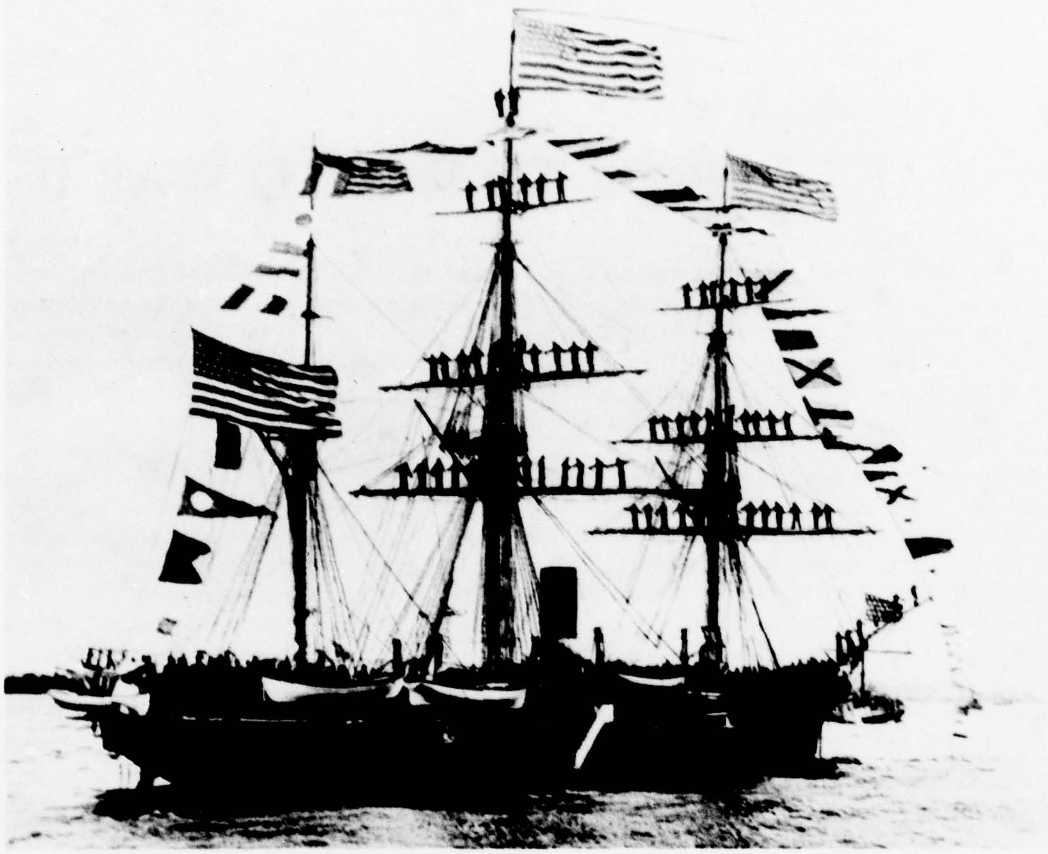

Figure 2-1. The Essex, a mid-nineteenth century warship combining sail and steam propulsion, displays her signal flags. In use since ancient times, signal flags were not standardized on a permanent basis until the seventeenth century.

At least two of the criteria for location of a command and control center in the age of sail still apply to modern naval operations. The decision-maker should have good access to executing officers, and he should be protected as much as possible from disruption and confusion. On the other hand, the need to exercise control by personal example has become much less important.

NINETEENTH CENTURY

The nineteenth century was a time of comparative peace, especially at sea. As the industrial revolution transformed Europe and the United States, the overwhelming might of the British fleet forestalled challenges to England's maritime supremacy and discouraged naval wars between other nations. From the destruction of the combined French and Spanish fleets at Trafalgar in 1805 to the Russo-Japanese War of 1904, there were fewer than half a dozen engagements between the battle fleets of major powers.

The century of relative peace at sea did not discourage innovations in warship design. By the mid-nineteenth century, steam-powered warships had replaced many of the graceful "ships of the line" that had fought at Trafalgar. Soon, iron, and then steel, supplanted wood for ship construction, while rifled guns in armored turrets replaced broadside batteries of smoothbore cannon.

The revolutionary changes in warship design had surprisingly little short-term effect on C^3 requirements, since they had only marginal impact on the critical parameters of platform speed and

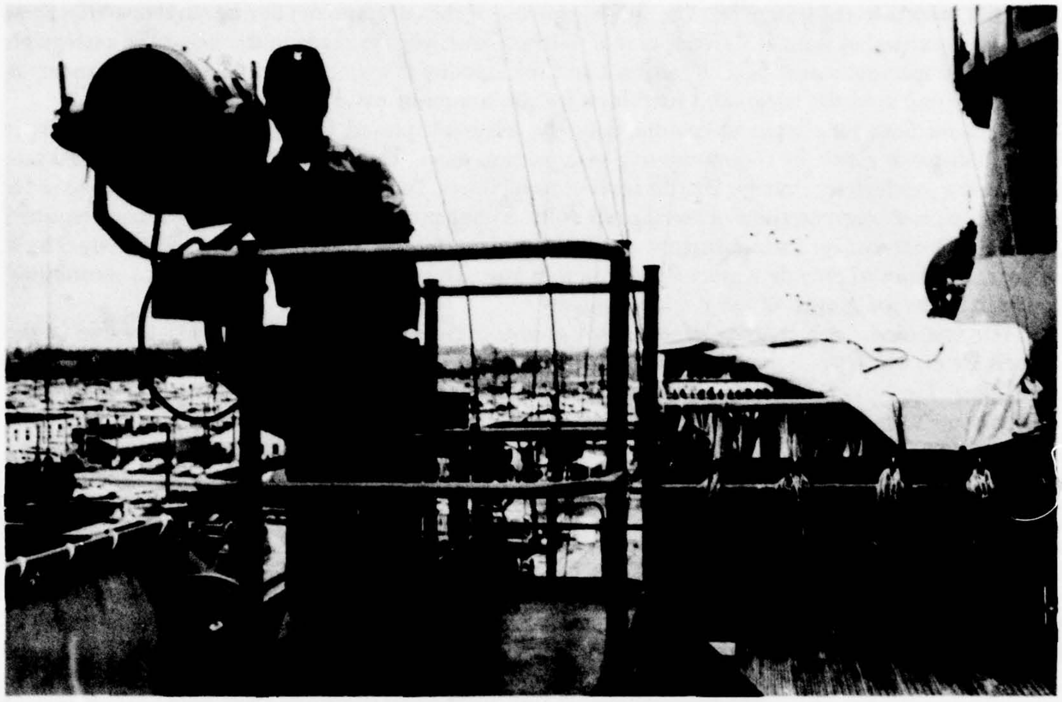

Figure 2-2. Equipping electrical searchlights with shutters for signalling was one of the first advances over traditional flag signals. Modern navies employ lights and flags for close-in signalling; note the "flag bag" to the right of the signalman.

weapon range. The large warship remained by far the most important naval platform in this period. The armored steam warships of the late 1800s no longer depended on the wind, but most were only a few knots faster than their wooden predecessors. Thus, Dewey at Manila Bay in 1898 could still maneuver his squadron efficiently using traditional flag signals.

Despite the invention of the self-propelled torpedo in the 1880s, the gun continued to be the principal naval weapon. The theoretical maximum range of naval guns had improved significantly, but lack of centralized fire control and modern optical range finding devices, which did not appear until shortly before World War I, constrained effective gun range to one or two nautical miles. At this short range, a commander standing on the bridge of the force flagship could personally observe the effects of his decisions and could exercise control in the traditional manner.

The most important communications advance of the nineteenth century was the telegraph, which placed central governments in much closer contact with shore facilities at home and abroad. During the Crimean War of 1854-55, a message relayed from the British Admiralty through the European telegraph system, thence by special undersea cable to the Crimea, could reach the local British naval commander within 24 to 48 hours. In comparison, lower priority dispatches, which continued to go by messenger and fast steamship, required between 16 and 24 days to reach their destination. The possibility of more direct participation tempted distant officials to interfere in the Crimean campaigns, to the confusion and consternation of local decision-makers. The commander of the French expeditionary force pleaded with his government to free him "from the restriction imposed on me....at the extremity, sometimes paralyzing, of an electric wire."* His request, of course, was sent by telegraph.

Despite the complaints of local commanders, the actual effect of the telegraph on tactics remained small. Telegraphic communications were too cumbersome and time consuming to permit long-range operational control. Naval operations, which almost invariably occurred beyond the reach of the

Hezlet, A., The Electron and Sea Power, *p 6, Peter Davies, Ltd, 1975*

telegraph, were affected least of all. The only tactical use of the telegraph net during naval operations was to report the arrival of ships at a given point or to report any sightings made in the vicinity of a telegraph station. The sporadic nature of such feedback and the inability to maintain contact with commanders at sea sharply restricted the telegraph's usefulness for the control of naval forces.

As a medium for command coordination, the telegraph proved far more useful. Increasingly, it replaced dispatch vessels for communicating with overseas bases. The telegraph system's higher data rate permitted a much closer strategic coordination of naval forces. For example, it was now possible to order the simultaneous concentration of naval units from distant points. Such far-flung operations required larger and better managed administrative and logistics organizations -- the former to handle a larger mass of data, the latter to provide a more flexible supply base. Thus, improved communications contributed considerably to the growth of naval establishments.

The late nineteenth century trend toward greater organization was particularly noticeable in the United States, which up to that time had lacked both an adequate shore establishment and a strong, seagoing fleet. The Navy Department, founded in 1798, had consisted for many years of little more than the Secretary and a few clerks. Weak harbor defense squadrons and a few ocean-going warships comprised the forces afloat. Not until 1842 did Congress establish a "Home Squadron" with at least the rudiments of a regular command structure. This structure proved adequate for blockade and riverine operations of the Civil War, but the Navy still lacked a central, uniformed command authority to plan and coordinate major fleet operations.

The need for a centralized command structure became more apparent towards the end of the nineteenth century. In 1883, the U.S. Navy embarked on a long-overdue program of ship construction and general modernization. Regular multi-ship exercises began for the first time with the formation in 1889 of a small "Squadron of Evolution"; but responsibility for naval operations remained divided among the autonomous technical bureaus of the shore establishment, and squadron commands at sea continued to exist largely on paper. This caused great confusion when the Spanish-American War began in 1898, and the Secretary of the Navy appointed an *ad hoc* Naval War Board to prepare strategic plans and advise him on day-to-day operations.

The naval reorganization following the war attempted to remedy these command deficiencies. Congress created a permanent "General Board" of high-ranking officers to resolve differences between lower-level organizations and to advise the Secretary on naval strategy, fleet movements, doctrine, and administrative matters. However, the General Board lacked authority, and a remarkable degree of decentralization persisted well into the twentieth century.

At sea, the Navy began to concentrate its ships into operational units. A squadron of armored cruisers was assigned to operate off the West Coast, while the growing battleship force concentrated in the Atlantic was designated the Atlantic Fleet in 1905. Large-scale training exercises, including the round-the-world tour of the Great White Fleet, became commonplace in the years before World War I.

The Navy's shore establishment continued to grow larger in order to deal with the logistics of steam navies and the information flowing from the world telegraph network. Nevertheless, the forces at sea remained beyond the day-to-day control of the shore-based high command, and commanders at sea had to base operational decisions primarily on their own visual observations.

COMMUNICATIONS REVOLUTION

Forces were already at work in the late 1800s that would soon revolutionize naval communications. Electric lanterns of different colors strung on flag hoists provided the first reliable method of night signalling in the 1800s. Searchlights were equipped with signal louvers about 1900, and were found to be sufficiently powerful to be read in daylight. At night, they could sometimes send messages over the horizon by aiming the beam at low-lying clouds. Flags were still favored in daylight, however, since they could be read from nearly all azimuths.

The first electronic development to have a radical effect on naval communications was the invention of the radio, known at first as wireless telegraphy, or "wireless." The electromagnetic signals produced by Guglielmo Marconi's transmitters before the turn of the century were practically omnidirectional and

were not affected by darkness or poor visibility. Most important, certain wavelengths soon demonstrated the ability to carry signals well beyond the horizon.

The application of wireless to naval operations was so obvious that Marconi took his invention to England, confident that the world's foremost naval power would appreciate its usefulness. The British Navy at first attempted to develop its own wireless equipment, but Marconi's sets proved far superior. Eventually the Admiralty purchased Marconi sets for testing in the fleet maneuvers in 1899. During the maneuvers, a cruiser equipped with a Marconi transmitter succeeded in sending vital tactical information to another cruiser 60 miles away. This was the first successful use of electromagnetic communication in a military operation.

The British fleet subsequently led the world in the development of wireless techniques, tactics, and "countermeasures." Wireless communication greatly assisted the British blockading squadron during the Boer War of 1900-01. Radio signals were intentionally "jammed" for the first time during the naval maneuvers of 1902. The following year, false signals were sent during maneuvers to deceive "enemy" ships monitoring fleet communications. The value of radio silence also became evident during these exercises. Thus, many essential elements of electronic warfare, such as electronic intercept, jamming, emission control and use of deceptive signals, came into use at a very early date.

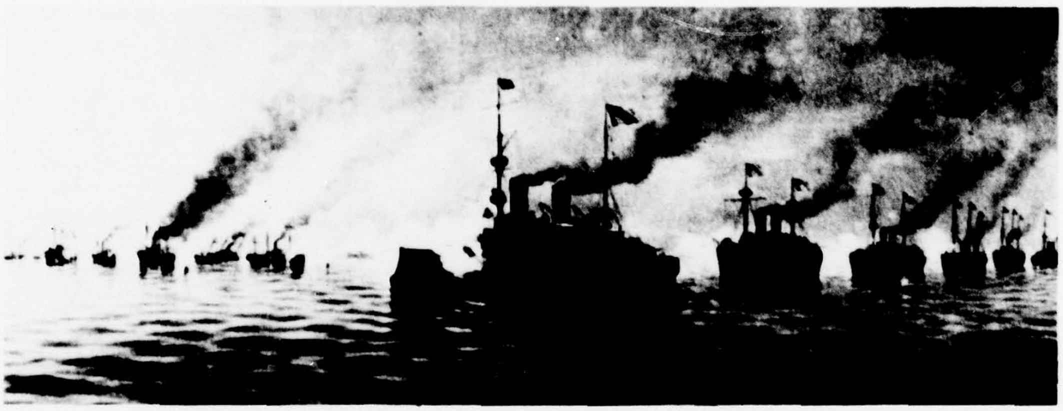

Figure 2-3. Commodore George Dewey could employ voice and flag commands effectively at the Battle of Manila Bay in 1898, but by World War I higher ship speeds, longer weapon ranges, and the development of radio made such traditional command and control methods much less effective.

All British ships larger than destroyer size had wireless sets by 1905, and the German, Italian, American, French, Russian and Japanese navies rapidly followed the British lead. Interference between transmitters soon became a problem. Early transmitters had used a single broad frequency, but even the broader frequency range of later equipment could not accommodate the rapid growth of wireless traffic. The British Admiralty therefore took steps in 1907 to impose strict radio discipline, including regular long-range naval broadcasts by shore stations. Specific frequencies were assigned to forces at sea, with given ships in a force assigned to monitor particular wavelengths.

The Russo-Japanese War of 1904-05 was the first conflict in which wireless played a major role. The Japanese employed it to relay scouting reports and to call the fall of shot during shore bombardments. The decisive Japanese victory at the Battle of Tsushima was made possible by the far flung Japanese scouting line, which reported the location of the approaching Russian fleet by wireless. The Japanese did not employ radio during fleet engagements, but directed tactics by use of visual means in accordance with pre-established battle orders. Radio procedures, which involved time-consuming relays, transcriptions and the passing of messages between the bridge and the radio room, were still too slow. Radio did not begin to supplant flags and lights for fleet engagements until the eve of World War I, when wireless procedures had become more efficient.

The Russians, unlike the Japanese, tended to be inefficient in their use of electromagnetic communications. Poor maintenance and operating techniques hampered the Russian Navy's attempts to use wireless to coordinate operations. But the Russians did demonstrate a talent for exploiting or frustrating enemy emissions, while controlling their own. Russian radio operators at Port Arthur frequently provided warning of the approaching Japanese fleet, and even succeeded in jamming Japanese signals during one naval bombardment. The Russian Vladivostok Squadron, by keeping strict radio silence and monitoring Japanese signals, managed on several occasions to evade Japanese warships and damage enemy commerce.

The U.S. Navy in the early 1900s showed a considerable flare for communications technology, but less aptitude for operations. In spite of serious communications problems encountered during the Spanish-American War, the U.S. Navy did not at once appreciate the value of radio. The first use of the new medium in fleet exercises did not take place until 1903. Senior officers considered radio unreliable, but sufficient enthusiasm existed in the shore establishment to proceed with construction of a wireless net covering the entire U.S. East Coast and much of the Caribbean. This net was completed in 1906.

The forces afloat used one radio frequency for all electromagnetic communications until 1911. Experimental voice radio was installed in 1907 in an Atlantic Fleet squadron about to make a round-the-world cruise, but the advanced equipment suffered frequent breakdowns, and at the end of its cruise the squadron beached the voice sets and returned to reliable Morse key sets.

As a rule, the quality of U.S.- manufactured radio equipment equalled or exceeded the quality of equipment manufactured in Europe. Ship installations, once begun, proceeded rapidly. By 1908 every ship in the Navy down to and including torpedo boats had transmitters and receivers. The result, unfortunately, was pandemonium. Operators neglecting to limit the power of short-range transmissions often blocked long-range communications from other ships. Private messages crowded the airwaves. Ships wishing to avoid undesirable orders feigned receiver malfunctions. Such malfunctions were frequent enough in any case, and were exacerbated by the number of equipment manufacturers and the lack of common parts.

The Navy took the first steps to establish order in 1912. A Radio Officer was appointed for the Atlantic Fleet, and a sufficient amount of circuit discipline was established to demonstrate that radio could provide reliable communications. The use of radio for tactical maneuvering and for calling the fall of shot during fleet exercises rapidly became the rule rather than the exception, but American radio techniques continued to fall short of those that prevailed in the major fleets of Europe. For example, the U.S. battleship squadron that reinforced the British Grand Fleet during World War I adopted British wireless procedures.

The less-than-two decades that separated the invention of radio from the advent of World War I had seen a spectacular growth in naval communications. At the end of the nineteenth century, Mahan could still characterize "the difficulty of obtaining information" as "a condition peculiar to the sea."* By 1914, radio nets spanned the shipping lanes, and naval forces routinely operated in contact with other friendly forces and with bases ashore. In theory, electromagnetic communications had extended the naval commander's "sight" far beyond the horizon by enabling him to receive real-time information from distant sources. Local decision-makers had much better access to decision-makers at higher levels of authority. Nevertheless, command and control practices did not keep pace with communications developments as navies sought to adjust their operating procedures to the new electromagnetic environment. To complicate the situation, electronic deception and countermeasures, ranging from radio silence to jamming, had developed almost as rapidly as wireless itself.

WORLD WAR I

Each of the world's navies had sought its own solutions to the problems raised by the communications revolution, and the effectiveness of those solutions helped to determine the course of World War I. The German Navy had developed a world-wide net of German long-range transmitters that gave the far flung units of the Imperial German Navy timely warning when the war began in August 1914. In contrast, some British ships narrowly escaped a surprise attack by Germans due to poor communications with the Admiralty in London.

*Mahan, p 466

The British recovered rapidly from this initial setback, dispatching forces to Germany's overseas possessions for the express purpose of destroying the powerful long-range transmitters, and generally deriving greater benefit than the Germans from the use of radio during the remainder of the conflict. British coastal stations soon intercepted German naval and diplomatic signals, and the Admiralty set up the first organization dedicated exclusively to deciphering radio codes. Using a number of captured and salvaged German code books, the naval intelligence unit, known as Room 40 for its location in the old Admiralty Building at Whitehall, came to play an important role in the war effort. The German High Seas Fleet, unaware that the British could intercept what they regarded as local signals, observed radio silence at sea, but made little effort to control the higher volume of radio traffic that almost invariably preceded a sailing. Although Room 40 could not always decode the German messages, preliminary signals usually gave some indication of approximate sailing time and the scope of impending operations.

Augmented later in the war by a net of coastal Direction-Finding (DF) stations, this communications intelligence gave England a tremendous advantage. Intercepted enemy messages regularly gave the Royal Navy early warning of enemy operations, often allowing the British fleet to get to sea before the Germans. Perhaps the most crucial contribution of communications intelligence was to relieve the British fleet of constant North Sea patrol duty, which early in the war had threatened to wear out large numbers of battleships.

Realizing the advantage they enjoyed, the British placed tight restrictions on their own radio emissions even in port. Both battle fleets maintained radio silence while underway, relying exclusively on visual communications. Scouting ships did use radio to report enemy sightings, however, and during an engagement the use of radio became general. As a rule, radio and visual signals were employed simultaneously during battle to provide maximum redundancy. The opposing fleets seldom attempted to jam one another's tactical transmissions, since more powerful transmitters and the growing range of available frequencies had reduced the effectiveness of jamming for the time being.

Radio became essential for controlling large fleets of fast warships armed with long-range guns. By 1914, battleships could make more than double the speed of their counterparts in the age of sail, and the more lightly armored battle cruisers were faster still. With main battle fleets approaching one another at a combined speed of nearly 40 knots, signal flags frequently proved too slow and unreliable. Admiral Sir David Beatty discovered this during the Battle of Dogger Bank when enemy shells cut off the electric power in his flagship. Beatty's crippled battle cruiser hoisted an incorrect flag signal as the other ships of his squadron sped past, sending them off in the wrong direction. The squadron was out of signalling range by the time the mistake was realized and corrected. While Beatty transferred to a destroyer and overhauled his wayward squadron, the enemy battle cruisers made good their escape.

The rangefinders and fire control directors developed in the years before World War I had increased the usual battle range from 2000 yards to eight miles or more. The greater standoff range made it difficult for the decision-maker to get a clear view of the action. To complicate the problem, smoke from heavy guns, coal-fired ships, and destroyer smoke screens obscured visibility. Only electromagnetic signals could maintain tactical cohesion in the resulting confusion. It is doubtful, for example, that the intricate ***Gefechtskehrtwendung***, a simultaneous, 180-degree turn that twice saved the German fleet from destruction at the Battle of Jutland, could have been carried out without radio control.

Fleet size also hindered the visual control of World War I engagements. Two decades earlier then-Captain Mahan had written that "The size and cost of the individual ironclad of the day makes it unlikely that fleets will be so numerous as to require subdivision."* But within a generation, the industrial nations had produced even larger and costlier ships in greater numbers than ever before. By 1914 it was impossible for the combined fleet of a first-rate power to maneuver within the visual cognizance of a single commander. At Jutland, for example, the 24 British battleships alone formed a line nearly seven miles long. Elaborate subdivisions of command had become the rule, and even radio communications sometimes failed to maintain contact with scattered units. The German fleet at Jutland was already engaging elements of the British fleet when the British commander sent out the message "Where is the enemy battle fleet?"

Although both the British and the Germans used radio extensively at Jutland and in other battles, the major fleet actions of World War I tended to be confused and inconclusive. This was due in part to the

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***Mahan, p 97**

fact that advances in weapons and communications had outpaced the development of information systems to support the decision-makers. Existing command and control arrangements could not deal with the confused mass of tactical data. There was little provision for displaying the data that was available. For example, the "admiral's plot" in the British flagship consisted of two staff officers who hand-plotted the positions contained in battle reports and intelligence notices. At Jutland this rudimentary system was expected to display real-time data on approximately 150 British and 100 German ships operated by a total of more than 100,000 men.

Changes in the critical parameters of platform speed, effective weapon range, and force size also tended to undermine the traditional rationale for locating the fleet command and control center in the main battle line. Putting the commander in a battleship no longer guaranteed the three basic elements of C^3: access to executing officers, timely feedback from engaged forces, and freedom from disruption. Transmitter damage could leave a decision-maker dependent on unreliable flag signals, and it was no longer easy for subordinates to follow the example of the decision-maker's ship. Visual limitations reduced the commander's ability to assess the total situation, but subordinates with a better view of the action often assumed that his information had to be better than theirs, and therefore failed to keep him properly informed. Important data on enemy movements and intentions now came via radio from shore, but the commander of a battle fleet could not always maintain sufficiently close radio liaison with these sources of information. Each of these deficiencies contributed to Admiral Sir John Jellicoe's inability to achieve a decisive victory over the Germans at the Battle of Jutland.

If the decision-maker had to remain at sea, the only platform that could bring him and his staff safely into contact with the enemy was a heavily armored dreadnought battleship. Accordingly, a number of steps were taken during and after the war to improve the battleship's C^3 facilities. Radio installations, when possible, were "duplexed," i.e., provided with equipment that could transmit and receive on the same antennas. The improvements also included the provision of two independent radio equipment spaces widely separated for maximum survivability. Both spaces were placed behind the armor belt, and were connected to an "information center" in the superstructure. The information center received all communications and passed them on to the nearby command and control spaces, which were considerably larger than those of earlier ships. This colocation of all C^3 functions in a single area of the ship marked the first step towards the later concept of a Combat Information Center (CIC).

The required level of centralized control was another C^3 issue brought to the fore by the complexity of World War I fleet actions. Germany and Britain each sought to deal with this problem in a characteristic manner. The Germans practiced every maneuver until the execution was letter perfect. Radio and visual communications were repeatedly exercised under simulated battle conditions. During actual battles, however, the German fleet commanders tended to give their subordinates a considerable degree of latitude in making tactical decisions. That the German fleet commanders failed to take full advantage of their more flexible command and control philosophy was due primarily to personal timidity in the face of the British naval tradition and the numerical superiority of the British Grand Fleet.

For their part, the British feared that the huge Grand Fleet would turn out to be unmanageable. Admiral Jellicoe, the British fleet commander, attempted to avoid confusion by providing for every contingency in advance. His detailed, voluminous "Battle Orders" put the preservation of a rigid, line-ahead formation above all else. He insisted on precise observance of flagship commands during fleet engagements. This command and control philosophy caused unnecessary confusion when the enemy made an unexpected maneuver. It also led to delay and lost opportunities when subordinates hesitated to act without proper signals from the flagship. This was a major cause of the German escape at Jutland.

SUBMARINE WARFARE

Although the North Sea fleet actions tended to be more dramatic, the U-boat campaign actually posed a greater threat to Great Britain and her allies. Ocean-going U-boats received long-range radio sets during the course of the war and reported to their bases by long-range radio after laying mines, running short of fuel, firing their last torpedo, or sighting Allied forces. The U-boats in turn monitored broadcasts from naval transmitters at Bruges and Nauen. Surprisingly, the German Navy in World War I made no

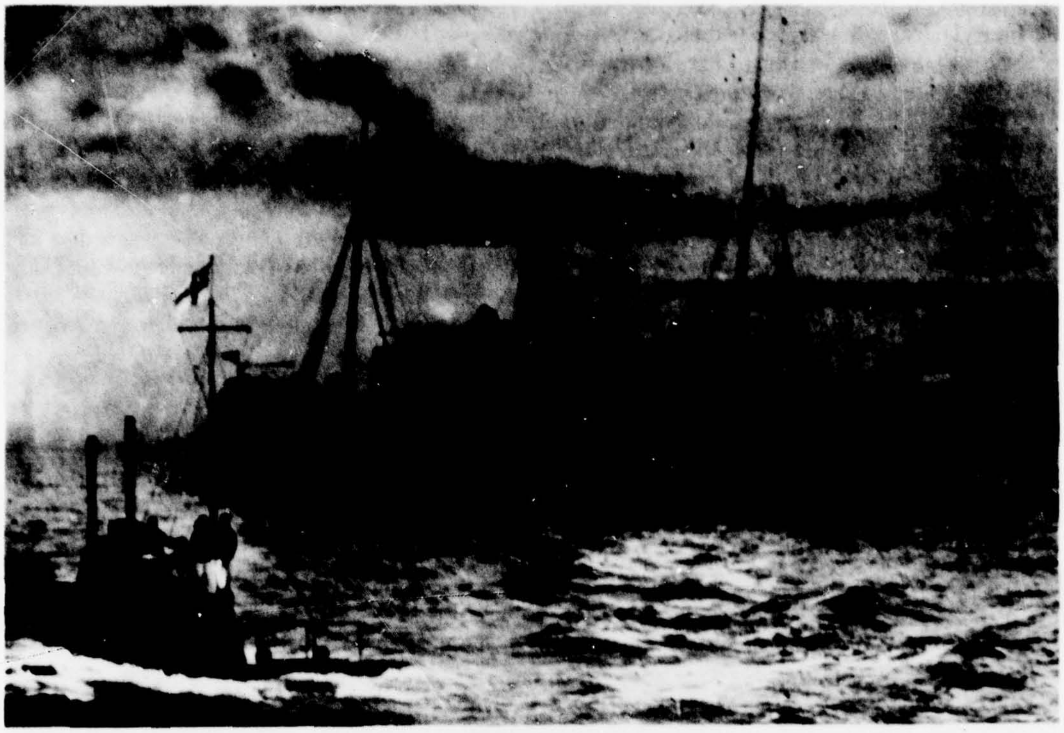

Figure 2-4. A German U-boat fitted with a radio mast halts a neutral merchantman early in World War I. It was during World War I that radio command and control, coupled with the exploitation of enemy radio signals, first provided the margin of victory, especially for anti-submarine warfare.

consistent attempt to exploit these two-way communications to gain a tactical advantage, although groups of U-boats did at times communicate among themselves to coordinate attacks on Allied convoys.

The Allies may have profited more than the Germans from U-boat signals. Rapid integration of data from anti-submarine units, direction-finding stations, and decoding operations gave the Admiralty a reasonably accurate picture of U-boat dispositions at any given time. This information contributed greatly to the success of convoys by enabling them to avoid known U-boat concentrations.

American anti-submarine units, unlike the U.S. battle force, played an important part in the naval war after 1917. Unlike British ships with radios requiring Morse code transmission, American ships were equipped with sophisticated, five-channel voice sets with pushbutton channel selection. These radios were very useful for convoy screens, since voice transmissions have greater flexibility and a higher data rate than transmissions in code. The U.S. Navy additionally pioneered the use of direction finders at sea, mounting them in anti-submarine destroyers to triangulate local submarine transmissions and to fix the relative positions of ships in formation. Knowledge of exact ship positions was helpful for screening and for hydrophone searches.

COMMAND CENTRALIZATION IN THE U.S. NAVY

The trend towards greater command centralization in the U.S. Navy had progressed considerably since the turn of the century. Four "Aides" to the Secretary of the Navy had been appointed in 1909 to supervise key areas of the naval establishment. The Aide for Operations rapidly became the most important of these officers. Command centralization progressed with the creation and definition in 1915-1916 of the Office of the Chief of Naval Operations. The Chief of Naval Operations had specific responsibility

for strategic planning and for the direction of fleet operations, but he could issue orders only in the name of the Secretary. His authority did not extend to the powerful bureaus of the shore establishment, which continued to report directly to the Secretary of the Navy.

The same trend affected the operational structure of the forces afloat following World War I. In December 1922, Congress created the U.S. Fleet as an operational command embracing all American naval forces. The new command consisted of two subordinate units: a Battle Force of capital ships and escorts, and a Scouting Force of cruisers and destroyers. With the defeat of Germany, U.S. attention turned towards Japan as the most likely naval threat. The newly created Battle Force was assigned to the Pacific, leaving only the relatively weak Scouting Force on the East Coast. The Commander-in-Chief U.S. Fleet (CINCUS) flew his flag in a ship of the Battle Force. This organization remained virtually intact until the German U-boat campaign in 1939-40 prompted President Roosevelt to foster the Atlantic "Neutrality Patrol."

TECHNOLOGICAL DEVELOPMENTS BETWEEN THE WARS

Electromagnetic communications had come of age in World War I. Radio was now installed as a matter of course in all types of naval ships and in aircraft. Radio had become essential for the command and control of naval forces. Exploitation of hostile communications had also become commonplace, although the jamming of enemy transmissions had grown less common because the proliferation of radio frequencies made it less effective than in the early days of single-channel transmitters.

The United States took the lead in many aspects of communications development. The U.S. Navy Radio Laboratory, set up in 1908 to develop experimental technology had been taken over by the newly established Naval Research Laboratory after World War I. The first radio test ship -- an old battleship -- was fitted out in 1920. Navy researchers also began to experiment with high frequency transmitters, which could attain long ranges with less power than low frequency sets. In 1925, researchers in Washington, D.C., were able to communicate in the high frequency band with the specially equipped cruiser *Seattle*, then in port at Melbourne, Australia. The success of this and other long-range experiments led to widespread installation of HF radio in U.S. ships during the late 1920s.

The Navy Radio Service had been the major American-owned ship-to-shore radio system since its establishment in 1912. Foreign-owned commercial stations were absorbed into the Navy system during World War I, giving the Radio Service a virtual monopoly on maritime and overseas radio communications. The federal government encouraged private American companies to enter this market after the war, but the Navy continued to play an important role for some time. Thus, the Navy was responsible for introducing high frequency shore stations during the 1920s, and for developing high-speed keying and recording mechanisms to increase the traffic handling capability of long-range circuits. The introduction of this equipment after 1924 marks one of the earliest applications of terminal automation to increase the flow of data.

In the fleet, the quality of electromagnetic communications lagged behind the development of new equipment. The adoption of British procedures and hardware by the U.S. battle squadron operating with the Grand Fleet had tended to forestall development of a modern and uniform system throughout the U.S. Navy. Peacetime retrenchment complicated the problem by degrading existing equipment and training.

The 1930 fleet maneuvers pointed out the deficiencies in radio communications and instigated a series of interim and long-term reform measures. Exercise ships of the "attacking" force kept strict radio silence and attempted to cause confusion by designating submarines to send false signals. The submarine signals proved superfluous because the "defenders" had already managed to jam their own communications with a plethora of emissions. Simple sighting reports took hours to break through the traffic. The corrective measures taken as a result of this fiasco succeeded in correcting the worst problems of training and equipment interface, but the lack of efficient communications procedures persisted into the early days of World War II.

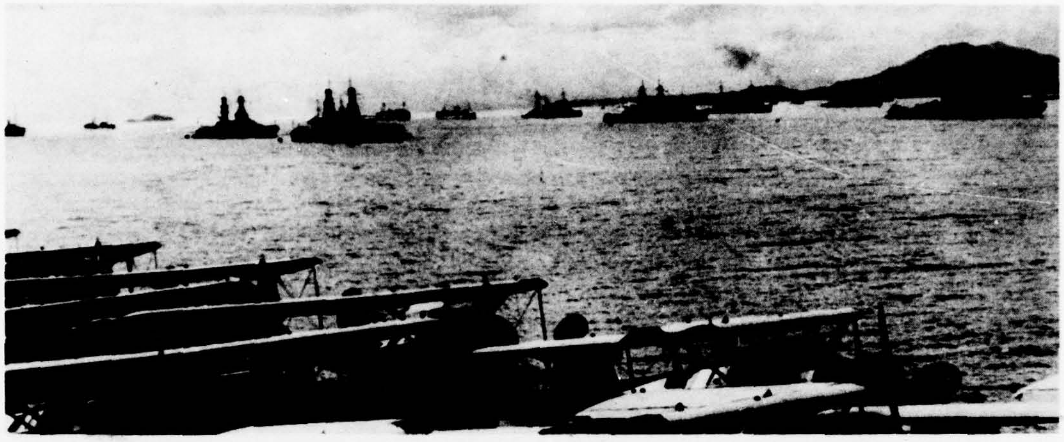

Figure 2-5. The U.S. battle fleet as seen from the deck of the aircraft carrier Lexington *(CV-2) during a 1929 fleet exercise. World War I showed that large fleets needed rapid and extensive communications, but the need for new command and control arrangements to handle revolutionary naval weapons such as the aircraft remained largely unappreciated.*

Naval ships built between the wars tended to be somewhat faster and better armed than their predecessors, but the most significant weapons system advances took place in other areas. Aircraft on the eve of World War II were several times as fast as those of twenty years before, and they could carry much larger bomb loads. This combination of speed and hitting power called for much more effective air defense. The development of radar in the 1930s gave the defense a key tool for detecting and tracking approaching aircraft.

Submarines also benefitted greatly from technological advances between the wars. The range, speed, and maximum operating depths of new submarines created a great potential for concerted anti-shipping campaigns spanning wide ocean areas. Many naval authorities in Great Britain and the United States believed that the invention of echo-ranging equipment, or sonar, in the 1920s had far surpassed the passive hydrophone sensors of World War I, and had therefore given the advantage to anti-submarine forces. But wartime experience would soon demonstrate that sensors alone could not defeat the combination of improved U-boats and new submarine tactics.

Command and control facilities, as distinguished from communications systems, developed very little between the wars. Shore facilities remained aloof from the operational control of forces at sea, whose commanders still relied on primitive, low-volume methods for data handling and display. But the steady development of weapon and sensor systems had begun to produce a growing, albeit latent, requirement for rapid and responsive command and control.

The latent demand for improvements in existing command, control, and communications systems grew with unforeseen rapidity during the years after World War I. In the field of communications, rapid evolutionary improvements offered a potential for meeting this demand by matching the range and speed of the new naval weapons and sensors. But in the relatively underdeveloped area of command and control, the need for responsive and effective systems would require technological and organizational changes similar to those in the communications revolution prior to World War I.

Figure 3-1. Radar antennas, such as these atop a U.S. Essex-class carrier, supplied the data needed for real-time control of World War II air defenses. Radar was first employed for this purpose in the 1940 Battle of Britain.

3
NAVY C^3 DURING AND AFTER WORLD WAR II

AMERICAN REARMAMENT, 1937-41

As a result of the 1930s economic depression, the United States reduced defense expenditures to well below the peacetime levels of the 1920s. The U.S. Navy attempted to maintain the size of the fleet by cutting manpower and postponing equipment modernization. The manpower cuts were distributed proportionally among specialties, but their effect on the communications specialty was particularly severe, as fewer communications personnel struggled to cope with an increasing use of fast, convenient radio messages by overworked officers. Procurement cutbacks compounded the problem, leaving the fleet with rapidly obsolescing radio equipment.

Communications requirements also increased during the pre-war years. Battle efficiency competitions emphasized the ability to handle large volumes of traffic without error. But, as is often the case, peacetime requirements and the procedures developed to meet them bore only a partial relation to wartime conditions. Navy communicators seldom attempted to simulate the confusion and disruption they would have to overcome in actual engagements. Important operational considerations, such as alternative message routing and electronic emission control, received relatively little attention.

Europe went to war in September 1939. Although America remained officially neutral, some U.S. units from the Pacific joined the Scouting Force in the Atlantic. The U.S. Navy began to render unofficial assistance to the British after the fall of France, with American destroyers extending more and more protection to the North Atlantic convoys. The U.S. Navy had already taken the lead in America's belated rearmament during the late 1930s, and naval communications had received a high priority. Ten percent of all uniformed Navy personnel were involved in some aspect of communications by 1939. The Defense Communications Board was set up in 1940 to plan the coordination of all military and civilian communications assets in the event of war. Members of the Board represented the two military services and various other government agencies.

Communications development became a major concern of the Navy shore establishment during the rearmament period, but organizational arrangements sometimes obstructed rapid increases in the development effort. As a result of the 1940 merger between the Bureau of Construction and Repair and the Bureau of Engineering, the Radio and Sound Division of the latter was reduced to a branch of the Development Division in the newly created Bureau of Ships. The temporary demotion of this understaffed group exacerbated the problems in dealing with a rapidly escalating workload.

The Bureau of Aeronautics soon began to play an important role in the design and manufacture of aircraft communications and navigation systems. Responsibility for installing these systems gradually devolved upon private aircraft manufacturers. Thus, the decentralized administration typical of Navy programs since the mid-nineteenth century began to affect communications electronics just prior to U.S. involvement in World War II. The tremendous growth of electronics requirements after Pearl Harbor spread the responsibility even further, leading eventually to the administrative diversity of present-day Navy C^3 activities.

Naval communications technology advanced rapidly. Work began in 1940 on the first Long-Range Navigation (LORAN) system. By early 1942, the Navy had completed a chain of LORAN stations from Chesapeake Bay to Nova Scotia. The first Navy teletype landline became operational in 1941, connecting naval facilities between Norfolk, Virginia, and Portsmouth, New Hampshire. Meanwhile, Great Britain had made significant progress with High Frequency/Direction Finding (HF/DF) and automated code

breaking, both of which enabled the Royal Navy to exploit enemy communications. U.S. support for the Allies prior to Pearl Harbor made the British quite willing to share these advances with the U.S. Navy.

Other electronic advances during the same period had important implications for the future of C^3. The Naval Research Laboratory had tested the world's first aircraft detection radar as early as 1932, and an experimental radar set went to sea in a destroyer in 1937. Unlike early fixed systems, U.S. shipboard radars soon incorporated a revolving antenna that permitted operators to obtain an approximate bearing on the contact. Subsequent operational evaluations of revolving antennas in the battleships *New York* and *Texas* confirmed radar's tactical potential.

Britain and Germany also developed radar independently during the same period. Britain, like the United States, emphasized radar's threat warning and tracking aspects, whereas the German Navy concentrated on the comparatively narrow function of long-range gun fire control. The British Navy produced the first airborne radar for patrol planes just prior to the outbreak of war in Europe.

Radar provided unprecedented amounts of tactical data. New systems were necessary to make this electronic data available to operators and tactical decision-makers. A Naval Research Laboratory report published in 1940 proposed that the Navy develop a radar repeater and a Plan Position Indicator (PPI). Radar repeaters made it possible to colocate sensor and communications terminals, and this soon gave rise to the concept of a Combat Information Center (CIC).

PPIs, the first of which was produced in 1941, replaced earlier cathode ray tubes indicating echo range only. The now-familiar PPI was the first electronic display to present a real-time situation in an easily comprehended, map-like format.

As the basic electronic components of future command and control systems began to emerge from defense laboratories, Britain's Royal Air Force (RAF) began the first integration of command, control, and communications over a large geographic area. The components of the new C^3 system -- telephone lines, manual displays, and large operating staffs -- involved no technological departures, but the systematic organization of these components to control distant forces was an important conceptual breakthrough. The term command, control, and communications would not appear for another two decades, but the Battle of Britain in 1940 gave birth to the underlying concept.

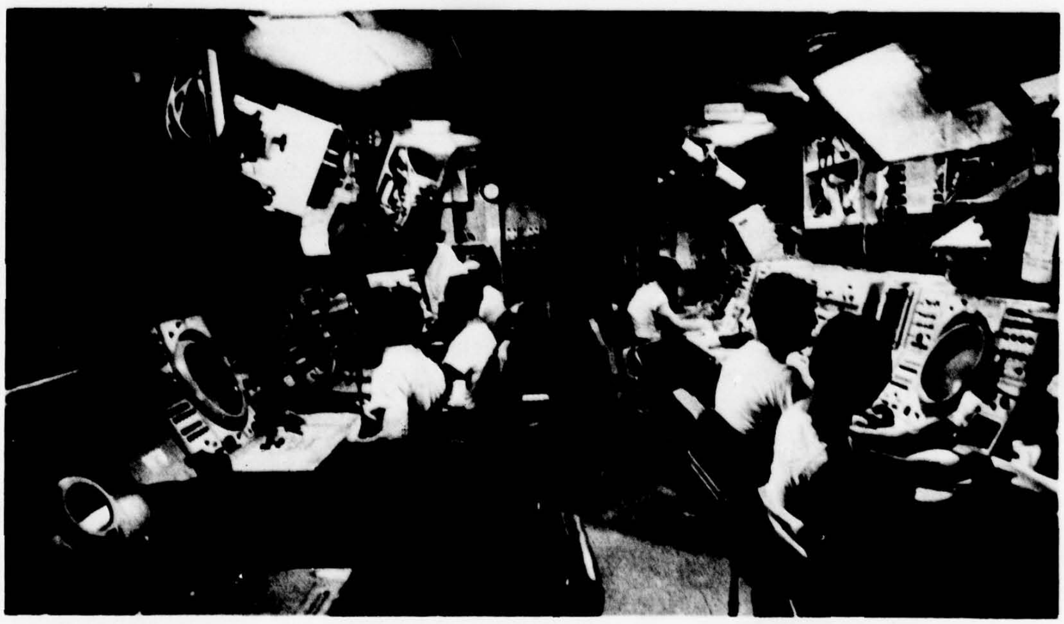

Figure 3-2. The automated Combat Information Center in a U.S. missile cruiser is the direct descendent of the manually operated CICs developed during World War II. The original CICs received only radar data and controlled only fighter aircraft; modern CICs receive all-source sensor information and coordinate many different combat operations.

Anticipating the speed and scope of World War II air battles, the RAF had made elaborate pre-war arrangements for controlling fighter groups assigned to strategic defense sectors. The RAF Fighter Command constructed an underground operations room for each fighter group, with telephone lines linking it to coastal radars, ground observers, intelligence activities, anti-aircraft installations and air bases. These sources provided the operations room with timely threat information and continuous feedback from the forces engaged. A large headquarters staff in the operations room and adjoining rooms processed the thousands of messages received during a battle. The resulting information was displayed on a large map plot of the region and on a two-story-high status board, with colored lights indicating the condition of each RAF fighter squadron.

The group commander occupied a glass-enclosed space above the plot, opposite the status board. He issued general directions based on his assessment of the changing situation, and an assistant seated nearby translated his orders into specific instructions for the forces under his command. The division of labor between a decision-maker, who issued general commands, and a subordinate, who managed the overall implementation of those orders, proved particularly successful, and has persisted in most subsequent designs for command and control facilities.

Winston Churchill, in Volume II of *The Second World War,* pays tribute to the aircraft of the Fighter Command, but credits the group operations rooms with providing the margin of victory:

> All the ascendency of the Hurricanes and Spitfires would have been fruitless but for this system of underground control centres and telephone cables, which had been devised and built before the war . . . . Lasting credit is due to all concerned.*

Superior C^3 may have given Britain victory over the German Luftwaffe, but the flow of operational data had already begun to increase more rapidly than the resources to deal with it. Churchill observed one major air battle in the operations room of the fighter group defending London and the South of England. After the battle, the group commander told the Prime Minister that "during the last twenty minutes we were so choked with information that we couldn't handle it. This shows you the limitations of our present resources."**

U.S. COMMAND ARRANGEMENTS, 1942-45

The Pearl Harbor attack of 7 December 1941 brought the United States formally into World War II. For the next three-and-one-half years, the war would involve more people and a greater portion of the earth's land mass than any other conflict in history. The scope of World War II necessitated both an extension of communications and a restructuring of Allied command arrangements.

The command structure of the U.S. Navy underwent considerable alteration in the early months of the war. Admiral Ernest J. King was appointed Commander-in-Chief U.S. Fleet shortly after Pearl Harbor. Several months later, he received the additional post of Chief of Naval Operations. Thus, Admiral King became the first officer to command both the Navy's operational forces and its policy and planning apparatus. This command consolidation achieved something approaching the unity of purpose advocated by naval reformers since before World War I. The separate post of Commander-in-Chief U.S. Fleet was later abolished.

Command integration, spurred by wartime necessity, progressed well beyond the bounds of the U.S. Navy. At the theater level, joint commands embracing diverse U.S. and allied armed forces became the rule. One of the earliest joint theaters was the Pacific Ocean Area Command. The Pacific Ocean Area Command did not include the Southwest Pacific Theater, which was kept separate for political reasons and assigned to General Douglas MacArthur, but it did embrace units of the U.S. Army and the Army Air Corps, as well as units from Allied navies. Admiral Chester Nimitz, Commander-in-Chief, U.S. Pacific Fleet (CINCPACFLT), had already followed the example of his immediate predecessors by commanding from his shore headquarters at Pearl Harbor. The addition of the Pacific Ocean Area Command

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**Churchill, WS,* The Second World War, *Vol 2, 1st ed., p 285, Houghton Mifflin Company, 1949*

**Ibid

to his duties as CINCPACFLT undoubtedly reinforced his earlier decision to keep his flag ashore, making him probably the first wartime naval commander in history to "lead" his forces from a shore-based command post thousands of miles from the scenes of action.

The North African and European Theater arrangements concerned mainly land and air forces. There an important consideration was resolving the rivalries between British and American commanders. U.S. Army officers held many of the more important theater commands in acknowledgment of U.S. logistics and manpower contributions and the U.S. commitment to make the European war its first priority. Except for naval forces assigned to amphibious and logistics operations, the British and U.S. navies avoided subordination to Allied theater commands in North Africa and Europe. In the Atlantic, the U.S. and British navies reinforced one another and pooled intelligence resources, but, in contrast to the situation ashore, they avoided any semblance of a joint naval command.

The U.S. armed services entered the war with only nominal interservice cooperation at the departmental level. A Joint Army-Navy Board had existed since 1903 to prepare national war plans and to coordinate other joint activities. Defense production needs had led to the formulation of a Joint Aeronautics Board in 1916 and a Joint Munitions Board in 1919, but interservice cooperation at higher levels was still, at best, sporadic. The British, on the other hand, had created a "Chiefs of Staff Committee" that met regularly with the Prime Minister or his representatives. This joint decision-making body enabled the British military to speak with a single voice in Allied councils.

When the British point of view prevailed more frequently than the American, the U.S. service chiefs responded with more frequent meetings to plan joint policy. This *ad hoc* U.S. joint committee had no legal standing except as a new variant of the old Joint Army-Navy Board, but gradually the term Joint Chiefs of Staff, which originally signified only the U.S. component of the combined American and British service chiefs, became the informal designation of the purely American group as well. However, the official chain of command still flowed from the President directly to each service secretary, then to the individual service chief. President Roosevelt's disinclination to deal with the armed services as a group reinforced existing interservice rivalries to discourage further emulation of the British model.

COMMAND AND CONTROL OF NAVAL FORCES IN WORLD WAR II

Command and control methods had evolved to the point that distant headquarters could exercise positive control of naval forces. The German U-Boat Command, under Admiral Karl Donitz, pioneered the direction of naval forces from shore-based command facilities. As Admiral Donitz stated in his *Memoirs:*

> My primary functions were to pass on to U-boats at sea all the information regarding the enemy which I received from a variety of intelligence sources, to correct or clarify any wrong or misleading information sent by the U-boats themselves, to issue orders to individual U-boats or groups, to coordinate the duties of maintaining contact, and to intervene in the event of contact with the enemy being lost. My control therefore extended up to the launching of an attack.*

Admiral Donitz' close involvement in operations contrasted sharply with the traditional British distaste for sending "rudder orders" to commanders at sea. But as so often happens, one way to defeat a centralized command and control system was to adopt greater centralization for one's own forces. The German system gave Great Britain excellent opportunities to decode German signals and to obtain HF/DF fixes on German U-boats, but the British could not exploit this opportunity to the fullest until they had set up a centralized ASW command to apply the cryptological and HF/DF information gathered by the Admiralty's Operational Intelligence Center (OIC).

The establishment of Western Approaches Command at Liverpool in late 1940 supplied the necessary C^3 structure to control British ASW forces in the crucial shipping lanes. Direct telephone and

*Donitz, K, Memoirs (RH Stevens, Trans.), p 63, Weidenfeld and Nicolson, 1959

teletype links connected Western Approaches' Liverpool Operations Room with OIC's highly secret Intelligence Plot and with the Admiralty's Master Plot, which controlled all shipping movements. Western Approaches also coordinated its activities with RAF's Coastal Command, which operated all land-based ASW aircraft. Direct, secure telephone communication among the various command and control centers enabled this apparently cumbersome arrangement to function smoothly by means of frequent conferences and conversations. The teletype system backed up the telephone net with a constant flow of appropriate data from one center to another. Western Approaches, with direct access by landline or radio to all escort bases and to ASW forces at sea, was the prime nerve center of British forces in the Battle of the Atlantic.

An interesting sidelight of the Battle of the Atlantic was the proximity of the two opposing commands. During many crucial phases of the struggle, the German U-boat command was located at Lorient, on France's Breton Peninsula. The Western Approaches Command headquarters at Liverpool was situated less than 400 miles due north. Yet most of the units commanded by these two installations were thousands of miles out to sea, spread across millions of square miles in their struggle to dominate the shipping lanes of the North Atlantic Ocean.

The United States began to learn the value of a unified shore-based ASW command in 1942, when the U-boat campaign shifted to American waters. Extremely high shipping losses helped British ASW and intelligence experts convince the Chief of Naval Operations to set up an American counterpart of the Operational Intelligence Center. But the U.S. ASW effort remained comparatively uncoordinated until mid-1943, when Admiral King created the Tenth Fleet, and appointed himself as its nominal commander. The U.S. Tenth Fleet was actually a naval staff organization combining convoy and routing, ASW, and intelligence functions. Officially, the Tenth Fleet merely advised the Commander-in-Chief, Atlantic Fleet, on ASW operations, but the role of Admiral King as its nominal commander gave this advisory organization effective control of the U.S. ASW effort. By the end of the war, shore-based command and control of Atlantic ASW forces had become even more centralized in the United States than in Great Britain.

Tactical control of fleet operations remained in the hands of commanders afloat. A striking force could not make frequent reports to a decision-maker ashore without giving away its position to enemy direction-finding. In any case, the speed of carrier air battles often prevented timely relay of operational data to a distant commander. Since shore-based C^3 facilities could play only a limited role in fleet operations, command and control arrangements at sea had to meet the growing data handling and display requirements of naval warfare.

The integration of valuable new combat technologies such as radar was one of the most significant command and control problems. The series of nighttime surface actions during the Solomon Islands campaign of 1942 showed the danger of relying on technological advances without appropriate provisions for C^3. Radar gave U.S. surface forces an enormous potential advantage in night actions, but the U.S. Navy had neglected its nighttime C^3 procedures, whereas the Japanese Navy had diligently practiced nighttime procedures developed prior to the invention of radar. Together with excellent long-range torpedoes, superior Japanese C^3 offset the U.S. lead in radar technology.

At the Battle of Savo Island in August 1942, an inferior Japanese force surprised and crushed a U.S. cruiser-destroyer force covering the landings on Guadalcanal. Inadequate recognition and communications procedures and faulty command arrangements contributed to the disaster. Radar-equipped destroyers failed to detect the approaching Japanese. American officers heard planes over head, but assumed that they were friendly until they began to illuminate the American ships with flares. Even when the Japanese opened fire, the U.S. cruisers responded slowly for fear of hitting friendly ships. After a few minutes one Australian and three U.S. heavy cruisers and one destroyer were sunk or sinking; the Japanese ships suffered negligible damage in the 32-minute battle.

Similar C^3 problems plagued the U.S. force sent out to ambush a Japanese bombardment squadron in the Battle of Cape Esperance. The radar-equipped U.S. ships found the Japanese first, but the American commander had placed his flag in a ship which lacked effective radar, thus depriving himself of timely battle information. Unable to check the identity of other ships' radar contacts, he delayed opening fire and lost the advantage of surprise. Once the fighting began, U.S. voice communications became clogged due to inadequate procedures.

The U.S. Navy soon began to improve its C^3 arrangements and make better use of radar in night actions. Circuit discipline -- a perennial problem -- had improved, as had reporting procedures and network protocol. New Combat Information Centers in larger ships rapidly correlated sensor and radio data to support ship and flag commanders.

The first payoff came in the Battle of Empress Augusta Bay in October 1943. There, U.S. ships held the Japanese at long range while maneuvering smartly to avoid Japanese torpedoes. However, neither force suffered serious damage. The first decisive American night victory came one year later in the Surigao Straits. In that battle, Admiral Thomas Kinkaid's battleships surprised and soundly defeated a somewhat inferior enemy squadron at the cost of one destroyer and a few small craft.

As in World War I, increases in the range, speed, number and diversity of platforms and weapon systems were the critical parameters that called for innovations in command and control. Aircraft carrier forces now attacked from ranges of several hundred miles with aircraft traveling at hundreds of knots. The intricacy of carrier operations called for maximum intelligence concerning enemy fleet dispositions, as well as timely warning of impending attack. Fleet air defense required real-time coordination of many aircraft and ship platforms of varying characteristics.

The use of radar and voice nets to control fleet air defense began with the successful defense of the carrier ***Lexington*** (CV-2) during an early 1942 strike on Guam. Radar detected 18 Japanese planes 76 miles from the ***Lexington***. The carrier launched fighters and vectored them to a successful intercept. In contrast to earlier British experience in the Mediterranean, the success of this operation indicated that properly controlled sea-based fighters could more than hold their own against land-based aircraft.

Development of command and control systems for fleet air defense progressed rapidly. The pace of air warfare and the need to coordinate fighter and anti-aircraft assets led to the development and proliferation of Combat Information Centers. More elaborate fighter-direction facilities became common in ships such as fast aircraft carriers, battleships, and amphibious flagships. New command and control arrangements melded these diverse C^3 centers into cohesive air defense systems. The U.S. air defense arrangements in the Battle of the Philippine Sea, which took place in June 1944, are typical. Overall fighter direction was in the hands of a single officer located in a large aircraft carrier. This officer kept an emergency reserve of airborne fighters under his personal command, but allocated most responsibility for countering incoming raids to four subordinate fighter-direction ships, each in charge of a specific sector. Officers in these four ships then allocated specific intercepts to other CIC-equipped ships within their sectors.

The highly coordinated U.S. air defense decimated the enemy attackers, destroying over 300 Japanese planes at a cost of only 30 American planes lost and slight damage to a single American ship.

The Battle of the Philippine Sea also marked the first time that U.S. destroyers served as radar pickets. Operating in the direction of the enemy at a distance from the U.S. main force, these ships helped solve the problem of detecting low-flying aircraft over the horizon. The pickets also helped to "delouse" returning U.S. attack squadrons which were sometimes followed by Japanese bombers attempting to disguise their approach among friendly radar contacts.

The major fighter direction facilities had a large number of tactical voice links to aircraft and other ships. Voice links were essential for World War II fighter control because no other existing communications mode could provide as high a data rate. Effective control of high-speed aircraft depended upon timely communication of large amounts of information. Most of the information on air defense plots and data boards therefore reached the command and control facility via UHF voice links.

Combat Information Centers were sea-going versions of the Operati- -n Rooms pioneered by the RAF. Manual or partially automated display plots integrated data from the ship's own radar with data from internal and external voice links. A large number of trained men were required to translate voice reports into coherent plots and display information. However, in an era of propeller aircraft and gravity bombs, manual data handling was sufficient to deal with the air threat.

Special "command ships" were another World War II innovation. These floating command posts came about in answer to the severe C^3 demands of amphibious operations. The landing of a large assault force against possible opposition required a greater diversity of naval, air, land, and amphibious elements than any other military operation. Moreover, precise timing was necessary to make the awkward transition from the shipboard environment to land combat as brief as possible.

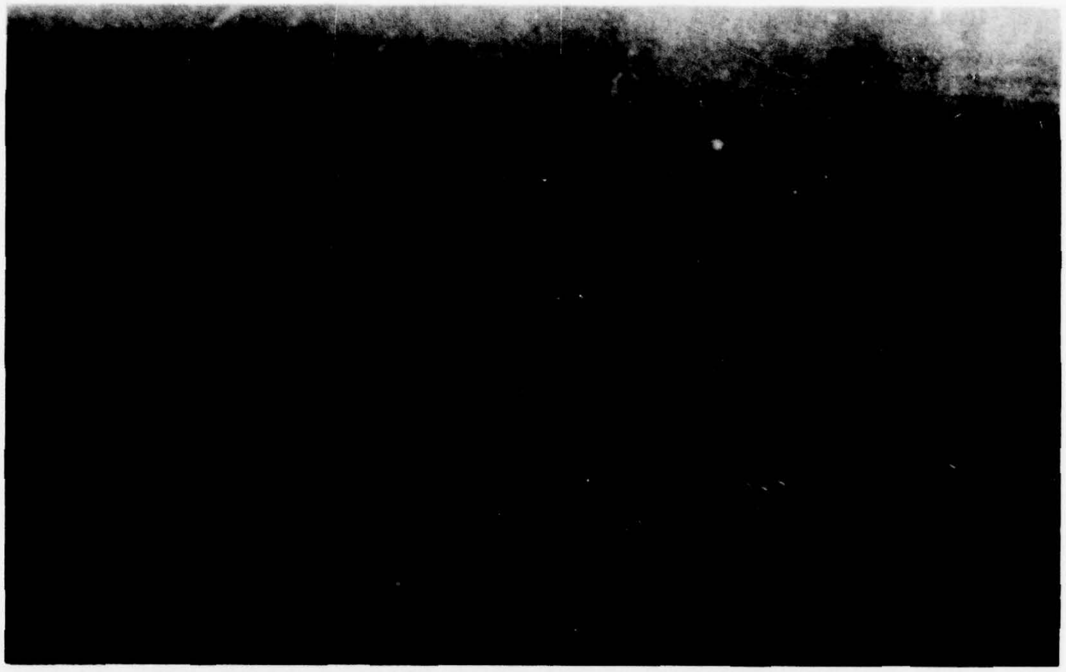

Figure 3-3. U.S. assault forces land in the Philippines in September 1944. Huge amphibious operations such as this landing posed the severest challenge to naval C^3 capabilities during World War II.

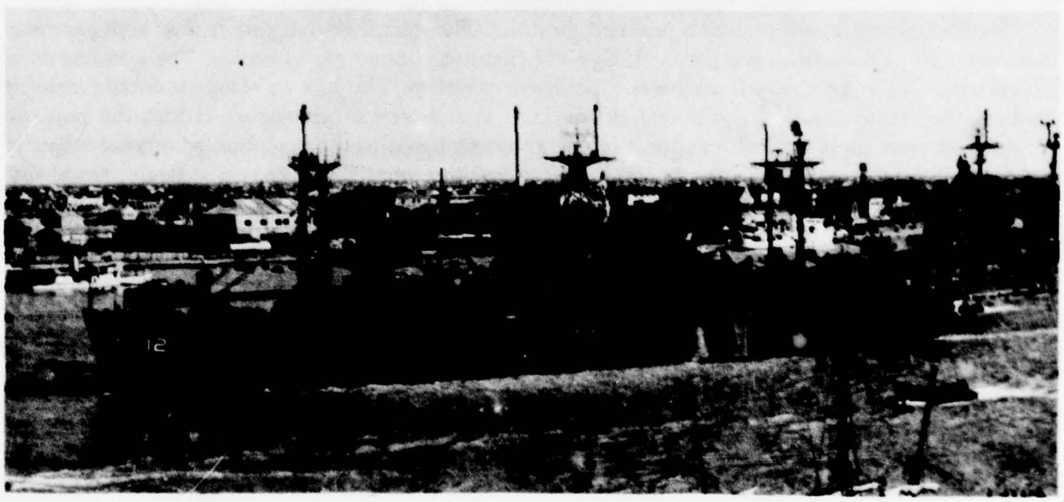

Figure 3-4. The Estes *(AGC-12), one of 23 U.S. amphibious force flagships specially configured to control large-scale landing operations, is shown here while serving as flagship of the U.S. Seventh Fleet shortly after the end of World War II.*

The Allied North African landings of 1942, although largely unopposed, became somewhat confused due to inadequate command and control. Special command ships would obviously be required in future amphibious operations. The British initiated the new ship type by converting the merchantman *Bolulo* to a landing ship headquarters (LSH) in early 1942. The U.S. Navy followed suit with the *Ancon*

(AGC-4), a former cruise ship and amphibious transport. The *Ancon*, the first of 23 Navy amphibious command ships built or converted during the war, proved her value as a command and control platform in the 1943 invasion of Sicily.

Amphibious command ships contributed greatly to the success of Allied landings, particularly during the logistically difficult "island-hopping" operations in the Pacific. The usefulness of complete mobile command and communications facilities in distant theaters was so apparent that Churchill had a British amphibious landing ship headquarters support him at the Casablanca Conference in 1943.

WORLD WAR II COMMUNICATIONS ADVANCES

As Admiral King noted in a post-war report to the Secretary of the Navy, "Perhaps the greatest technological advances of the entire war have been in the field of electronics." He specifically cited "highly efficient short-range radio telephones...for tactical communication"* as one of the most important electronics advances. The VHF and UHF voice frequencies used by U.S. ships and aircraft could accommodate more message traffic than lower frequencies. The Japanese found VHF and UHF communications very difficult to intercept, both because transmission paths are primarily line of sight and because Japanese forces often lacked suitable intercept equipment. U.S. carrier task forces made extensive use of VHF to control their combat air patrols without betraying their position. Groups of three or four U.S. submarines used VHF, in conjunction with radar, to coordinate multi-axis attacks on Japanese convoys, whose escorts remained unaware of the U.S. signals.

Wartime communications advances also included the multiplexing of radio equipment and the introduction of frequency shifting to increase the flow of traffic. Teletype became common for long-range point-to-point communications and some teletype broadcast nets were established, thus freeing skilled radio operators for more pressing assignments. Associated electronics developments included radar identification systems,** radio and radar countermeasures, and automated cryptographic analysis. Automated cryptography, which included the use of first-generation electronic computers, enabled the Allies to read most German and Japanese naval codes during the greater part of the war.

Some communications problems persisted, however. The volume of traffic more than kept pace with improvements in transmission capacity. U.S. Navy circuit discipline was often lax. The assignment of unnecessarily high message priorities was a persistent problem. The lack of complete interoperability between the communication equipment of the U.S. armed services also persisted into the post-war period. However, these difficulties appear minor when compared to the herculean accomplishments of melding all British and U.S. military communications into what amounted to a single, worldwide communication system.

NAVAL COMMUNICATIONS SINCE WORLD WAR II

Joint operations in the Korean War once again highlighted the lack of interoperable communications among the various U.S. armed services. Navy close air support sometimes failed to make contact with Army control teams on the ground. Gunfire support ships encountered similar difficulties. Coordination improved as the war progressed, but in many cases the Navy found it necessary to provide its own fire control teams on the battlefield. Despite subsequent standardization efforts, lack of equipment commonality would continue to hinder interservice communications during joint operations.

The pace of technological development remained high during the 1950s. Researchers found that pointing a highly directional VHF or UHF antenna towards the horizon produced an effect called ionospheric forward scatter, which allowed signals to reach points hundreds of miles over the horizon. Navy communicators could employ this phenomenon to fill many of the medium-range "gaps" in normal HF coverage. Meanwhile, the development of single sideband communications greatly increased the data rate and signal strength of long-range signals in the higher frequencies.

Howeth, LS,* **History of Communications-Electronics in the U.S. Navy, *p 400, Bureau of Ships and Office of Naval History, 1963*

***Identification Friend or Foe (IFF).*

Frequencies at the other end of the spectrum, which could penetrate water to a significant depth, came into use during the 1950s for submarine communications. With the deployment of ballistic missile submarines in the early 1960s, the role of VLF communications in strategic operations expanded significantly.

The advent of satellite relays was clearly the most important communications development of the 1960s. The Soviet Union, which had launched the first artificial satellite in October 1957, took an early lead in developing satellites for naval communications. The Soviet Navy demonstrated the effectiveness of this new medium for real-time control of widespread naval forces in the multi-ocean OKEAN exercises of 1970 and 1975.

The United States did not lag in the development of communications satellites, but the U.S. Navy and the other armed services preferred to rely on older communication methods until satellites had demonstrated their high value and reliability. ECHO I, launched in 1960, was the first U.S. commercial relay satellite. A large inflatable sphere, ECHO I served as a passive reflector for "bouncing" signals to distant points on earth. TELSTAR, launched in 1962, demonstrated the commercial practicality of smaller, solar-powered satellites which actively repeated the signals they received. At about the same time, SYNCOM satellites of the National Aeronautics and Space Administration (NASA) pioneered the

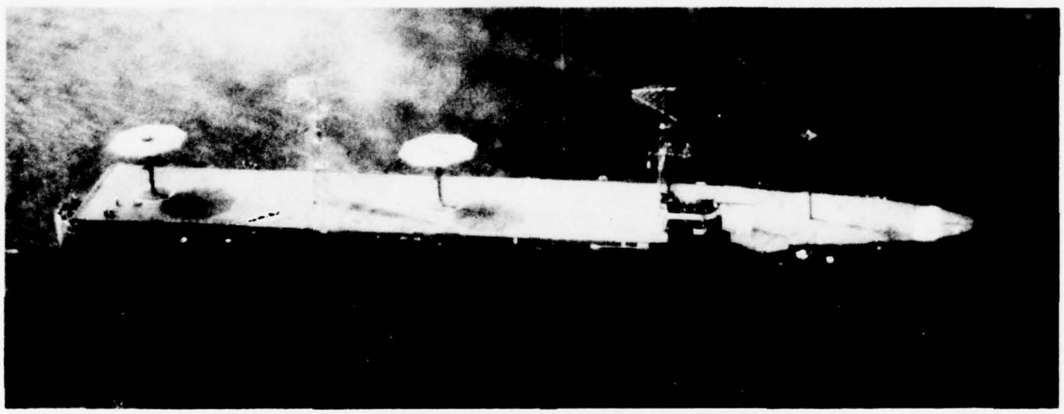

Figure 3-5. The Annapolis *(AGMR-1), a former escort carrier converted to serve as a communications relay station, alternated with another converted carrier on station off Southeast Asia during the late 1960's. Greater use of satellites for long-haul defense communications led to the retirement of both ships in 1969.*

use of a high-altitude, geosynchronous orbit, in which the satellite kept station directly above a given point on the earth. EARLY BIRD I, a Communications Satellite Corporation (COMSAT) satellite launched in 1965, successfully employed this technique to provide a more or less permanent communications link between geographic points in a given area.

Communications satellites had several advantages over other communications media. They provided dependable UHF links over great distances. They had a large message capacity, they were relatively resistant to interference (including jamming), and they were six times more economical to operate than undersea cables.

Meanwhile, escalating American involvement in Southeast Asia was demonstrating the deficiencies of standard military communications. The failure of HF communications, for example, sometimes aborted gunfire support missions off Vietnam and frustrated underway replenishment operations in the Tonkin Gulf.

The type of patrol, surveillance and interdiction operations carried out in Vietnam called for an unprecedented volume of communications traffic, as did the frequent, long-range consultations to modulate the scope of the conflict. Navy communications bore much of the traffic. In the Western Pacific, ship-to-shore traffic alone increased from 77,000 to 270,000 messages per month between 1964 and 1967. A Navy

radio station in Vietnam that went on line in 1967 handled 120,000 messages in the first month of operation. New stations also had to be built in Australia and elsewhere. To deal with some of the load, the Navy reactivated two small World War II aircraft carriers and equipped them as communications relay ships. Throughout the late 1960s, these ships, the *Annapolis* (AGMR-1) and the *Arlington* (AGMR-2), relieved one another at regular intervals in the South China Sea.

While the individual services continued to rely on conventional links, the Defense Communications System, which dealt primarily with high-priority Department of Defense and National Command Authority (NCA) messages, began to use satellite channels in the NASA SYNCOM and COMSAT EARLY BIRD satellites. The *Canberra* (CAG-2), while off Vietnam in April 1966, became the first ship to receive a satellite message, relayed by SYNCOM from the Naval Communications Station in Honolulu.

Twenty-six small satellites of the Initial Defense Satellite Communication System (IDSCS) were placed in low equatorial orbits between 1966 and 1968. This purely defense-related system could relay teletype, voice, image and digital data. The first of four larger, higher-orbiting satellites in DSCS Phase II went into orbit in 1971. The Phase II satellites each had two steerable dishes to beam messages from NCA to small, portable radio sets in specific crisis areas.

The U.S. Navy began to lease relays on COMSAT's commercial Maritime Satellite in the 1970s, pending the scheduled 1977 initiation of the Fleet Satellite Communications (FLTSATCOM) system. FLTSATCOM links, on the same satellites which carry the Air Force Satellite Communications (AFSATCOM) relays, carry high-priority messages for Navy aircraft, ships, submarines, and ground stations. They also provide communications interface with Strategic Air Command and NCA communications nets. Together with the NAVSTAR Global Positioning System, a series of satellites which will provide very precise locational data to surface and air platforms, FLTSATCOM will provide the basis for a dramatic improvement in Navy C^3 capability

Although each service has pursued its own tactical communications programs since World War II, a significant portion of long-haul communications has come under the auspices of the Defense Communications Agency (DCA), set up in 1960 to supervise the merger of growing Navy, Air Force, and Army landlines and fixed radio nets into a single Defense Communications System (DCS). Since carrying out this merger, DCA has turned to the development of certain systems initiated by the various services, among them the Automatic Digital Network (AUTODIN) data and teletype system, the Automatic Voice Network (AUTOVON) military telephone system, and the Automatic Secure Voice Communications network (AUTOSEVOCOM), a largely manual secure voice net. AUTODIN, for example, was derived from an existing Air Force logistics net, while AUTOSEVOCOM benefited from a Navy system used in the Pacific during the mid-1960s. The largely analog equipment which makes up the present DCS reflects the communications state-of-the-art exemplified in these early Air Force and Navy systems.

U.S. NAVY COMMAND AND CONTROL SINCE WORLD WAR II

The changes in the military chain of command during the late 1940s were greater than any that had taken place since ratification of the U.S. Constitution in 1789. The National Security Act of 1947, which created a separate Air Force, was further amended in 1949 to unify all the services under the Department of Defense. The service secretaries lost their cabinet rank and were removed, along with the uniformed service chiefs, from the chain of command. Operational authority now flowed, in theory, from the President to the Secretary of Defense, then to theater commanders at home and abroad. As members of the Joint Chiefs of Staff (JCS), the service chiefs could advise the Secretary and the President on military matters, but, despite a 1958 amendment establishing the post of Chairman and giving the JCS a permanent staff, the operational role of this organization remained limited.

In the case of the Navy, the uniformed service chief retained a considerable amount of direct control many years after the 1947 merger. The Chief of Naval Operations no longer had the legal authority to command operations, but he did have the rank, the expertise, and the necessary C^3 facilities. In the Cuban Missile Crisis of 1962, for example, Admiral George W. Anderson personally directed the blockade and submarine harassment activities from the Naval Operations Center in the Pentagon. Moreover, he actively attempted to discourage Secretary of Defense Robert McNamara from interfering with these operations. Previous Secretaries of Defense had allowed the CNO to take charge of crisis opera-

tions, but Secretary McNamara was determined to exert a greater degree of civilian control. He believed that the President and his subordinates must be able to direct and, if necessary, restrain U.S. tactical forces during a confrontation with the Soviets or their proxies. In an era of potential nuclear holocaust, the stakes seemed too high for operations such as this to be handled at any level below the National Command Authority.

The most significant obstacle to direct civilian control was the lack of C^3 support. The Office of the Secretary of Defense was an administrative organization poorly suited to directing operations. Although the individual services had C^3 systems for supporting limited conflicts and nuclear responses, they lacked a means whereby the President and his civilian subordinates could deal directly with potentially hazardous crisis situations. The apparent solution was to create a separate "crisis" system in addition to the "war-fighting" command and control systems of the various services.

A second aspect of civilian command and control which required attention during the early 1960s was the security of the National Command Authority. The direct involvement of the American high command in a crisis area might increase the temptation for an enemy to attack the NCA in an attempt to disrupt U.S. retaliatory capability. The credibility of the U.S. deterrent depended on the survivability of a properly constituted civilian commander and his C^3 support.

Secretary of Defense Robert McNamara attempted to meet the survivability and civilian control requirements by means of the newly established National Military Command System (NMCS). NMCS included alternate land, airborne, and afloat command posts for the NCA, in addition to the underground National Military Command Center at the Pentagon.

The *Northampton*, a former task force flagship (CLC-1), was redesignated CC-1 and assigned as the first National Emergency Command Post Afloat (NECPA) in 1961. The fact that this ship needed only limited modification for its new role indicates the sophistication of the naval command and control systems developed during and after World War II. The mothballed light carrier *Wright* (CVL-49) was reactivated to become the second NECPA (designated CC-2) in 1963. Supported by special communications stations in Delaware, Massachusetts, and North Carolina, these ships alternated on station within helicopter range of the White House during the 1960s. However, improvement of Soviet maritime surveillance and targeting gradually eroded the survivability of the floating national command posts, and both the *Northampton* and the *Wright* were laid up in reserve during 1970.

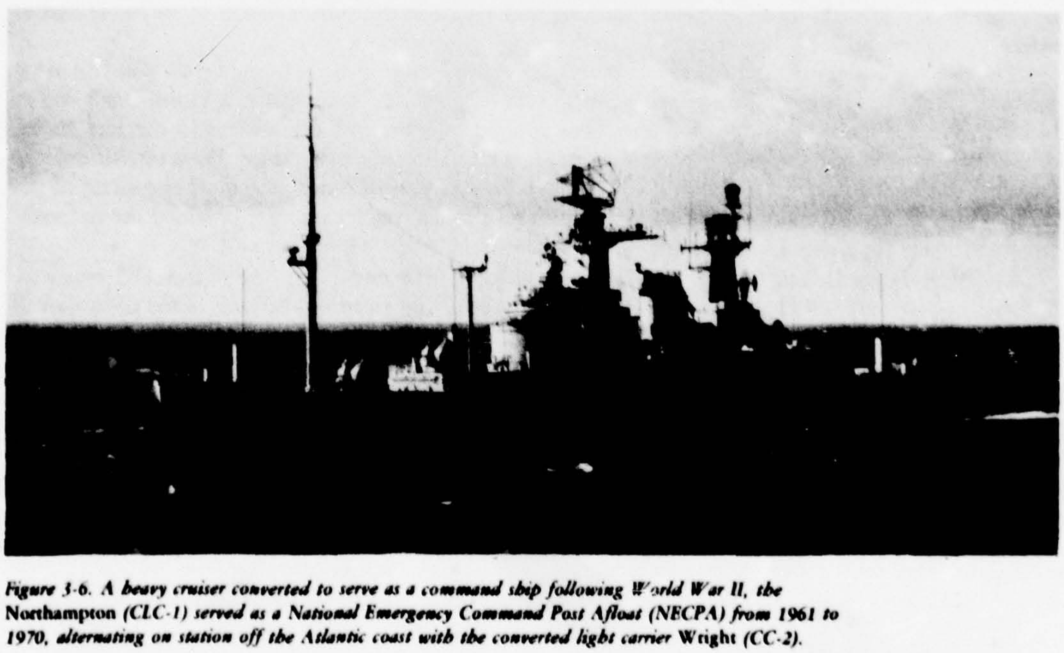

Figure 3-6. A heavy cruiser converted to serve as a command ship following World War II, the Northampton *(CLC-1) served as a National Emergency Command Post Afloat (NECPA) from 1961 to 1970, alternating on station off the Atlantic coast with the converted light carrier* Wright *(CC-2).*

While the NCA survivability problem appeared solvable, the problem of direct civilian control over U.S. forces in a crisis area continued to concern Secretary McNamara. He sought to close the command and control gap by setting up the World-Wide Military Command and Control System (WWMCCS). Essentially data and communications support for NMCS, WWMCCS was a computer system designed to provide civilian decision-makers with complete information on U.S. force dispositions and to set up the desired communications with local and regional commanders.

In the 1967 *Liberty* incident and the 1968 *Pueblo* incident, when virtually unarmed, isolated intelligence-collection ships were attacked in international waters, DoD communications proved much too cumbersome. The intricate and unreliable automated systems became glutted with irrelevant data and could not provide suitable communications links. The President and his advisors resorted instead to the largely manual military telephone systems, which, although slow, gave them direct contact with regional commanders. Control of operational forces once again devolved upon naval authorities in the Pentagon.

These failures led to a reform of WWMCCS under the direction of the newly created Office of the Assistant Secretary of Defense, Telecommunications (now Command, Control, Communications and Intelligence). But the evacuation of Saigon and the capture of the *Mayaguez*, both of which occurred in 1975, demonstrated that WWMCCS had yet to become the responsive decision-making tool envisioned over a decade earlier. Once again, national decision-makers discarded the unwieldy system in favor of traditional methods.

The automation of command and control below the NCA level was more successful, albeit not without many initial difficulties. The major drivers of strategic and tactical command and control automation were the air and missile threats, and the electronic computer.

When automated systems first began to appear in the early 1950s, the Soviet strategic bomber was considered the principal threat to U.S. security. Large, subsonic bombers gave defenders several hours to respond between initial threat detection and nuclear weapons delivery, but the vast distances involved and the severe penalty for every bomber that penetrated called for rapid and precise coordination of U.S. defenses. The North American Air Defense Command (NORAD) was established in the 1950s to correlate information from air defense radars, to coordinate interceptors and anti-aircraft missiles, and to alert NCA and U.S. nuclear strike forces.

Manual systems could not keep pace with the huge amount of data that NORAD had to handle. Only electronic computers coupled with highly automated display systems could process raw data into useful information and present it in a coherent fashion for rapid decision. This became even more true as ballistic missiles reduced intercontinental warning and response times from hours to minutes, and as missile submarines added a new dimension to the problem of threat evaluation.

The use of automated mechanical computers for gunfire control dated from World War I. Analog electronic computers were employed during World War II to aid in decoding enemy radio signals and to direct anti-aircraft guns. Analog computers were applied to other military systems in the late 1940s, including integrated underwater fire control systems for new anti-submarine ships. However, air defense remained the most important field for computer application. The new digital computer systems of the 1950s, which packed far more processing capability into a much smaller volume, provided the necessary speed and scope for a new generation of air defense command and control systems.

The Naval Tactical Data System (NTDS), the product of the mid-1950s LAMPLIGHTER review of U.S. Navy air defense, employed shipboard digital computers and electronic displays in the control of all task force fighter and AAW defenses. The most significant feature of NTDS was direct data communication between distant ships. This enabled the CIC of an NTDS-equipped ship to "see" real-time sensor information from several platforms. The supersonic speed of late-1950s aircraft and AAW missiles made such multi-platform sensor correlation an essential element of fleet air defense.

The first shipboard NTDS installations completed at-sea evaluation in the carrier *Oriskany* (CVA-34), and the missile ships *King* (DLG-10) and *Mahan* (DLG-11), in mid-1962. Carriers, major amphibious ships, and task force missile escorts built or modernized after the mid-1960s received NTDS as a matter of course. The proliferating Soviet missile threat led to NTDS installation in a wider variety of combatant types during the 1970s. Newer installations incorporated improvements in ASW and anti-surface capabilities as well as improvements in AAW response time, but the Soviet Navy's increasing

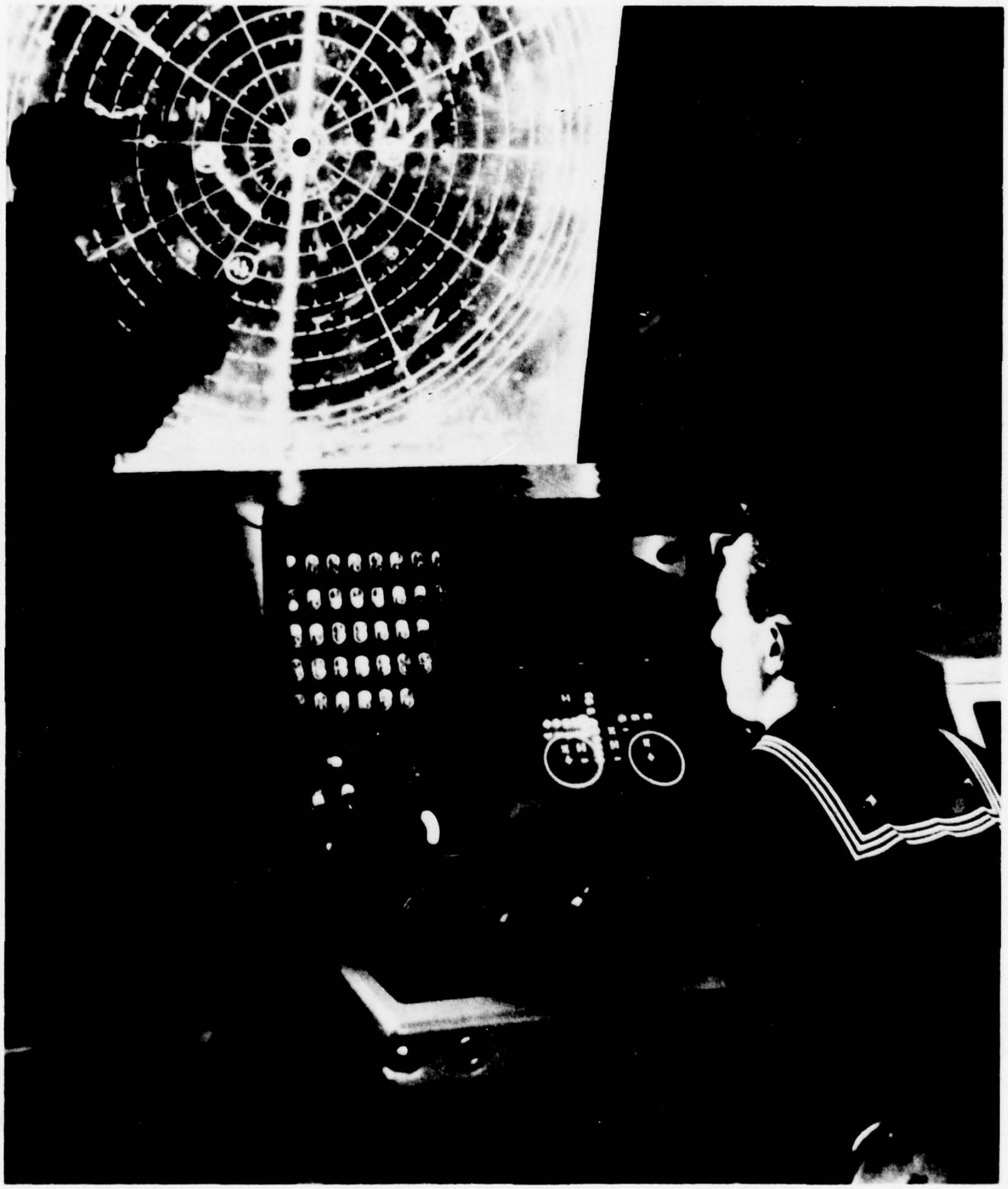

Figure 3-7. During the 1960s, Naval Tactical Data System equipment, such as this computerized tracking console, replaced cumbersome manual plots like the one in the background. Manual plots have been retained in command and control spaces as an emergency backup for automated systems.

ability to launch coordinated missile attacks continued to reduce the relative effectiveness of NTDS for fleet air defense.

The original NTDS shortened response times by sharply reducing the human role in data processing and presentation. This had the additional benefit, once the bugs had been worked out of the system, of reducing manning requirements. In general, the trend toward automation in the 1960s and 1970s has tended to reduce the number of operators for command and control systems, although not without some increase in the required number of maintenance personnel. The Aegis air defense system, developed to meet the cruise missile threat of the future, has taken this trend one step further.

Aegis is essentially a sensor/fire-control system that incorporates many tactical command and control functions in order to deal automatically with high speed threats. Timely control of an Aegis ship's missile firepower during a multi-axis surprise attack does not always leave room for positive human control. Therefore, Aegis has a pre-selected operating mode in which the system itself makes the tactical decision to engage based on given threat criteria. In this mode, the role of the human decision-maker is to decide for what period this limited, automatic "if/then" decision apparatus should be in control.

Automation has also taken hold at higher levels of naval command and control. The flag plots of World War II force commanders have become large command and control installations with their own computer support. The trend toward larger command and control spaces was apparent in the light cruisers (CLG-3 class) converted to AAW missile configuration in the late 1950s. Four of the six ships received a fleet flag installation in addition to their missile conversion. These four ships had to land a triple 6-inch gun turret and two 5-inch mounts forward to provide additional C^3 spaces. Similarly, the two amphibious command ships (LCCs) built during the late 1960s displaced over 7,000 tons more than the World War II-era AGCs they replaced. To counter this trend, the proposed Tactical Flag Command Centers (TFCC; see Chapter 5) would use a higher level of automation and closer cooperation with shore installations to give task group and amphibious force commanders more command and control support in a smaller space.

Automated data processing and display systems also play an ever-increasing role at the shore-based Fleet Command Centers (FCC), the modern equivalent of the British Operations Room at Western Approaches Command. However, the proposed FCCs at Pearl Harbor (CINCPACFLT), Norfolk (CINCLANTFLT), and London (CINCUSNAVEUR) will differ from their World War II predecessors by providing for the control of not only ASW units, but the entire range of general-purpose naval forces. Finally, the Naval Command Center (formerly Naval Operations Center) at the Pentagon provides the Chief of Naval Operations or his deputies with the capability to control fleet operations whenever and wherever necessary.

In short, automated, worldwide naval C^3 has become a reality despite problems of reliability and efficiency that still appear from time to time. Automation has become more and more routine for both civilian and military tasks, and reliability has improved as operators and users accustom themselves to the new systems. With a better understanding of the strengths and limitations of its automated C^3 systems, the U.S. Navy can now turn to current-generation tactical applications and to the next-generation system developments that promise to multiply the effectiveness of weapon and sensor systems, and to help compensate for declining Navy force levels.

4
NAVAL COMMAND ORGANIZATION

CHAIN OF COMMAND

Many factors have influenced the current structure of the U.S. military chain of command. Operational requirements are foremost, but electronics technology, institutional patterns, and even the leadership styles of individual decision-makers have also played a significant role. In the last two decades, the danger of military confrontations in an age of nuclear weapons and intercontinental missiles has prompted senior decision-makers to maintain closer contact with local forces during crisis situations. Real-time communications, automatic data processing, and electronic display technology make this possible.

The current chain of command for U.S. forces recognizes both the operational requirement and the technological capabilities by making the U.S. Commanders-in-Chief for Europe, the Atlantic, and the Pacific directly responsible to the Secretary of Defense and, through him, to the President. This arrangement, which bypasses the JCS and the military and civilian heads of the Army, Navy and Air Force, makes sense from a technical point of view, but it could not have come into existence without the influence of powerful institutional factors. The specific institutional factors involved were the traditional American desire for strong civilian control of the military, the pressing need to resolve post-World War II rivalries among the Army, Navy and Air Force, and the proven efficiency of having one man command all forces in a specific geographical area. The best way to accomplish both goals was to place the Secretary of Defense directly above joint commanders in the field, leaving the service headquarters in Washington outside the military chain of command.

Despite the existence of strong personalities at various levels of authority, the key to understanding the defense command organization is the concept of decentralized authority. The United States has always favored divisions of power. Our political tradition emphasizes cooperation among equals with separate but complementary responsibilities. This organizational principle applies to a surprising degree even within the relatively hierarchical structure of the American military.

NATIONAL COMMAND AUTHORITY

The President of the United States is the Commander-in-Chief of the U.S. Armed Forces. The Secretary of Defense, the President's immediate subordinate, serves as the day-to-day decision-maker in defense matters. Together, the President and the Secretary of Defense -- and designated alternates -- constitute what is called the National Command Authority (NCA), empowered to command all U.S. combat forces. The President and the Secretary of Defense also supervise the administration of U.S. military forces, the procurement of supplies and equipment, and the development of future military systems.

Thus, the men who constitute the National Command Authority have a great deal of authority in the various areas of broad command. However, the military powers of the President, and even more so those of the Secretary of Defense, are limited by the Constitution, by congressional legislation, and by the workings of the executive branch. The President, for example, cannot declare war and cannot conduct hostilities for more than 60 days without congressional approval. Congress must approve all military expenditures, including the additional amounts needed to sustain operations above the normal peacetime operating tempo.

The powers of the Secretary of Defense are modulated by other offices outside of the Defense Department. The President's Office of Management and Budget has a great deal of influence in administrative and procurement matters. More importantly from a command and control standpoint, the National Security Council (NSC) has a strong voice in a broad range of military decisions. The regular

members of the NSC are the President; the Vice President; the Secretaries of Defense, State, and the Treasury; the Chairman of the Joint Chiefs of Staff; and the Director of the Central Intelligence Agency. The official who coordinates the NSC's activities and who reports regularly to the President on defense matters is his National Security Advisor.

ADMINISTRATIVE CHAIN OF COMMAND

Below the level of the Office of the Secretary of Defense (OSD), the chain of command for naval operating forces follows two lines of authority, one for administration and another for operations. The purpose of this division is two-fold. At the service level, it fulfills the institutional need for civilian control and the balancing of service interests by enabling the service headquarters to support deployed forces without intervening in the joint command system. At the fleet level, it relieves fleet and task force commanders of the administrative workload that would otherwise distract them from their primary task -- the command and control of combat forces.

Figure 4-1 presents a simplified version of the administrative chain of command for the naval operating forces. The administrative line of authority begins with the Secretary of the Navy and his uniformed subordinate, the Chief of Naval Operations (CNO), who has no command authority under the present system. The CNO is essentially a manager, responsible for logistics, maintenance, personnel management, procurement of naval systems and supplies, and research and development. He does not plan naval campaigns or conduct naval operations unless the National Command Authority specifically orders him to do so.

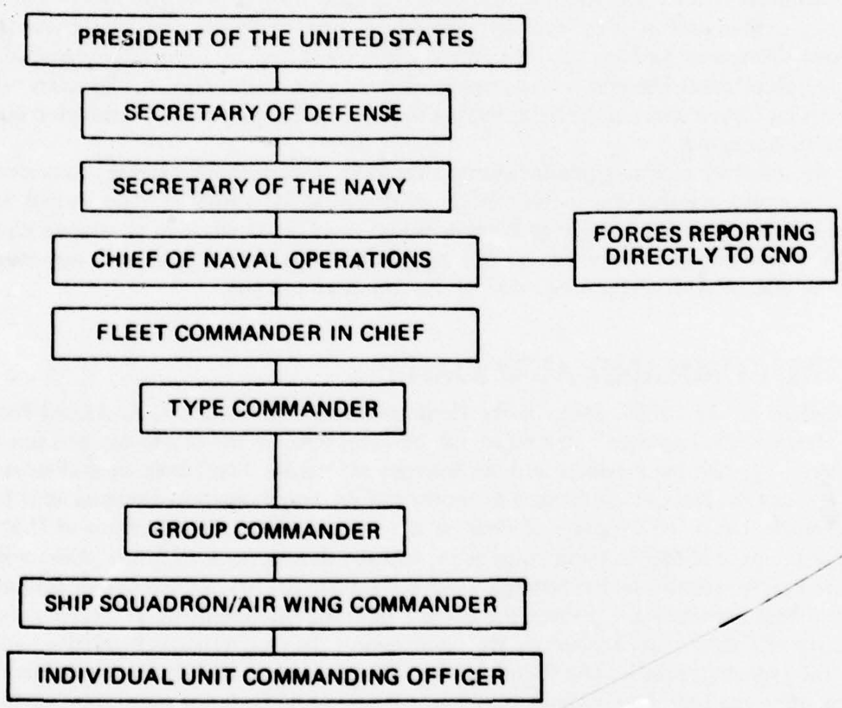

Figure 4-1.
Administrative Chain of Command for U.S. Navy Operating Forces.

The prime task of the CNO is to support the operational commanders. To accomplish this task, the Office of the Chief of Naval Operations (OPNAV) has a large staff of specialists in the various fields of naval expertise. While the administrative chain below CNO has only an indirect impact on naval command and control, it is necessary to take a brief look at its relation to the operating forces in order to understand the context in which U.S. Navy command and control systems operate.

Some aspects of administration such as recruiting, procurement, administration of naval facilities, and research and development, fall primarily within the scope of the "shore establishment." Responsibilities in these areas are carried out by the CNO and his subordinate, the Chief of Naval Material. They do not call for the rapid communications and real-time decision-making typical of tactical command and control systems. Where naval administration functions directly support the operating forces, the distinction between operational and administrative responsibility, while still important, tends to be somewhat less precise. Although the administrative chain of command seldom runs perfectly parallel with the operational command, many commanders in the fleet "wear two hats," i.e., hold positions in both chains of command.

The administrative functions within the fleet generally pertain to "readiness." This includes both material readiness -- the maintenance and logistics that enable naval systems to function as required -- and training. The Commanders-in-Chief of the Atlantic and Pacific Fleets (CINCLANTFLT and CINCPACFLT), in addition to their operational duties, share the responsibility for supervising the administration of the "forces afloat," including certain land-based activities and units in their areas of responsibility. CINCLANTFLT has administrative cognizance over all units in the Atlantic and Mediterranean. The two fleet CINCs report to the Chief of Naval Operations on administrative matters.

Each of the two major fleets has four subordinate type commands to supervise specific categories of units: the naval air force (which includes aircraft carriers), naval surface force, submarine force, and training force. These "type" commanders are based ashore. Their responsibilities include keeping track of casualties and ship movements, monitoring exercises, establishing and updating operating regulations for ships and aircraft, and supervising the movement and activities of all ships and aircraft not currently assigned to any operating force. Even when assigned to a force at sea, units of a given type report regularly to their type commander on their status and activities.

Type commanders usually have no operational function as such, but are double-hatted as task force commanders to be activated if and when it becomes necessary to command operational forces. Two type commanders head active operational forces in addition to their administrative duties. The submarine type commander in the Atlantic (COMSUBLANT) heads the Submarine Force, Atlantic Fleet, which controls all deployed submarines not specifically assigned to another command. His counterpart in the Pacific (COMSUBPAC) has similar responsibilities as head of the Submarine Force, Pacific Fleet. This separate operational command arrangement for submarines reflects the unique command and control problems associated with coordinating their operations with surface and air forces and, to some extent, their strategic attack role.

Below the type commanders in the administrative chain are the officers in charge of groups (e.g., cruiser-destroyer groups), and their subordinates in charge of ship squadrons and aircraft wings. Most administrators at these levels are also commanders of operational units, although the scope of their administrative jurisdictions may vary significantly from the scope of their operational commands. At sea the distinction becomes somewhat blurred, and existing command and control systems may be called upon to handle part of the administrative workload of group, squadron, and air wing commanders. Nevertheless, administration remains a secondary consideration in the design of command and control systems. While it must be taken into account and suitable facilities provided, it should not be permitted to detract from the primary purpose of command and control, which is the real-time direction of forces in order to achieve operational objectives.

OPERATIONAL CHAIN OF COMMAND

The Secretary of Defense (SECDEF) is the civilian decision-maker most closely involved with the direction of military operations. He commands the Unified and Specified Commands, as indicated in Figure 4-2. This chart, like most illustrations of the U.S. high command, places the Joint Chiefs of Staff between SECDEF and the major operating commands. Although technically correct from a communications standpoint, this is somewhat misleading, since the role of the JCS is strictly advisory, and is not part of the National Command Authority.

The membership of the JCS consists of an appointed Chairman, the Chief of Naval Operations, the Chiefs of Staff of the Army and Air Force, and the Commandant of the Marine Corps. Their duties are to advise the President and the Secretary of Defense on military matters, provide advice and guidance for the individual services, and maintain the support facilities of the National Military Command System (NMCS). NMCS facilities include the National Military Command Center (NMCC) at the Pentagon, two

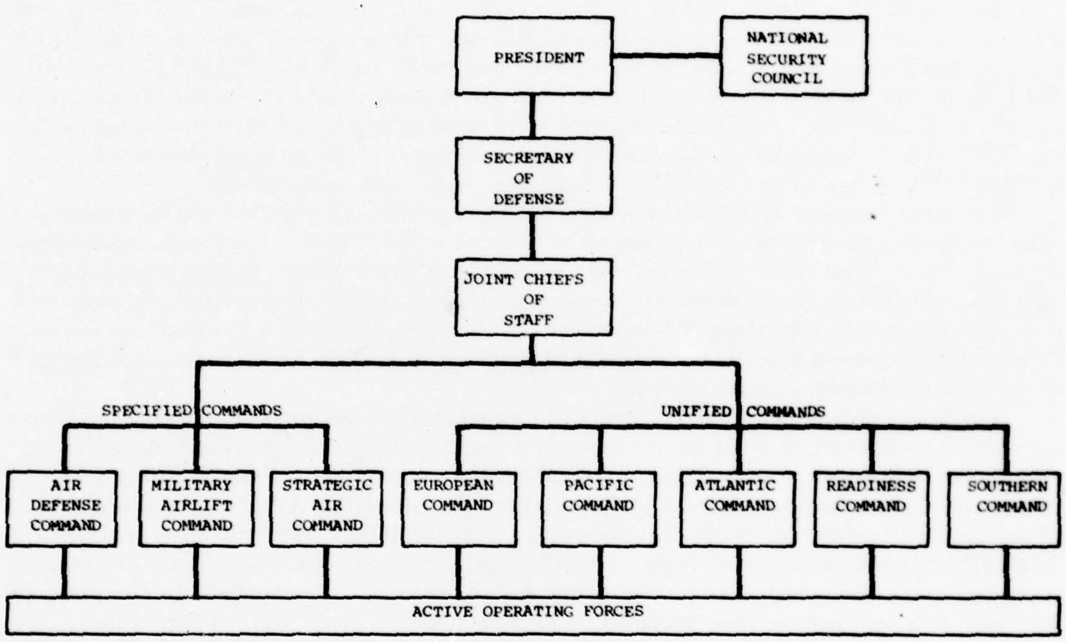

Figure 4-2.
U.S. National Defense Command Structure.

Alternate National Command Centers (ANMCC), and the World Wide Military Command and Control System (WWMCCS). WWMCCS consists of automated long-range communications and extensive data processing facilities which are intended to permit the NCA to take direct command of U.S. military units anywhere in the world. A Joint Staff of several hundred officers drawn from the four services assists the JCS with these duties.

The Chairman of the JCS outranks all other active-duty military officers during his term of office, sits on the National Security Council, and commands the Joint Staff, but he may not issue operational commands to the forces in the field unless directed to do so by the Secretary of Defense. His role, and that of the JCS as a body, is limited to ensuring that the National Command Authority has the benefit of the military point of view and direct command access to the heads of the Unified and Specified Commands.

The United States maintains three Specified Commands and five Unified Commands. The Specified Commands -- the Aerospace Defense Command (ADCOM), Military Airlift Command (MAC), and Strategic Air Command (SAC) -- are organized to perform the specific military functions implied by their

titles. They consist largely of Air Force units. Except for MAC, which provides air transport for all services, the Specified Commands operate mainly within the continental United States.

A Unified Command usually contains components from more than one armed service and carries out a broad range of general-purpose and strategic missions. The Pacific Command (PACOM), Atlantic Command (LANTCOM), European Command (EUCOM), and Southern Command (SOUTHCOM) are responsible for operations in the geographic regions shown in Figure 4-3. The Readiness Command is a non-combat organization set up to control a central reserve of U.S.-based Army and Air Force units.

The Commander-in-Chief (CINC) of a Unified Command is customarily chosen from the service that makes the largest contribution in that theater. Since each service component handles its own administration with the support of the service headquarters in Washington, the headquarters of the Unified Command is theoretically free to concentrate on planning and training for military campaigns. The most important function of a Unified Commander is therefore the command and control of U.S. forces in his theater.

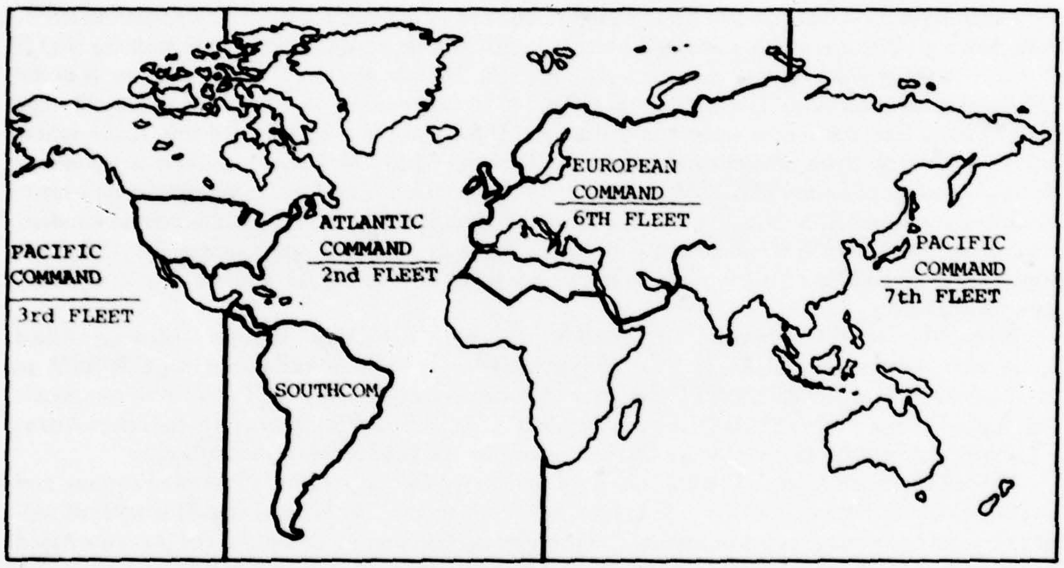

Figure 4-3.
U.S. Unified Commands and Numbered Fleets.

The three main Unified Commands, PACOM, LANTCOM, and EUCOM, are task oriented. They include whatever mix of service components is required by their missions. PACOM includes Air Force units in Japan and Guam, an Army Division in Korea, a Marine Amphibious Force (division and air wing) divided between Okinawa and Oahu, and the numerous naval units and facilities of the U.S. Pacific Fleet. PACOM is under the command of the Commander-in-Chief, Pacific (CINCPAC), traditionally a four-star admiral with headquarters near Honolulu. Under him are two component commanders in charge of Navy and Air Force operations, respectively. The U.S. Army, which makes the smallest contribution in the Pacific, does not currently maintain an active component command in that theater.

The Commander-in-Chief, U.S. Pacific Fleet (CINCPACFLT), is the naval component commander. From his headquarters in Pearl Harbor, he coordinates the activities of the Commander, Third Fleet, also based at Pearl Harbor, and the Commander, Seventh Fleet, who flies his flag in a command ship homeported in Yokosuka, Japan. In addition, CINCPACFLT coordinates operations under the control of COMSUBPAC, who does not report to a numbered fleet commander.

The Atlantic Command includes only Navy components. The Air Force and Army do, however, keep representatives on the staff of the admiral who serves as Commander-in-Chief, Atlantic (CINCLANT). In peacetime, LANTCOM consists primarily of the Atlantic Fleet, and even LANTFLT units leave LANTCOM's sphere of command when they enter the Mediterranean. Because CINCLANT's peacetime responsibilities as a Unified Commander are limited, he serves in addition as Commander-in-Chief, U.S. Atlantic Fleet (CINCLANTFLT). In effect, he is his own naval commander. Finally, as if this officer lacked a sufficient number of "hats," he serves as Supreme Allied Commander Atlantic (SACLANT), in command of all NATO naval forces in his theater. This activity is largely for planning except during a major NATO crisis or war, since few naval units are assigned to this NATO command during peacetime.

Reporting to CINCLANTFLT are the Commander, Second Fleet, with headquarters in Norfolk, and several separate operational commanders. The Second Fleet, like the Third Fleet in the Pacific, maintains a lower state of readiness than the forward deployed fleets and serves in peacetime as an operational reserve force to reinforce the Mediterranean or other crisis areas as necessary. The other subordinates include Commander, Submarine Force, Atlantic Fleet, who controls most operational submarines in the Atlantic, and the commanders of anti-submarine warfare sector groups who control land-based patrol aircraft during ASW operations.

The European Command embraces a greater number of service components and a greater variety of forces than any other major U.S. command. Moreover, EUCOM is very closely integrated with the NATO alliance, and many of its key commanders hold important, but not necessarily comparable, posts in the NATO chain of command. The head of EUCOM is the Commander in Chief, U.S. Forces Europe (CINCEUR), a four-star officer traditionally from the U.S. Army or Air Force. His immediate subordinates in the U.S. chain of command are the heads of the Army, Air Force, and Navy components. Although most naval forces in EUCOM operate in the Mediterranean, the naval component commander, Commander-in-Chief, U.S. Naval Forces, Europe (CINCUSNAVEUR), has his headquarters in London. From there, CINCUSNAVEUR directs assigned forces, primarily those under the Commander, U.S. Sixth Fleet (COMSIXTHFLT), who has some headquarters facilities near Naples and his flag in a cruiser homeported nearby.

When the NATO command organization is active, CINCEUR becomes Supreme Allied Commander, Europe (SACEUR), and the fairly straightforward line of authority from CINCEUR to CINCUSNAVEUR to COMSIXTHFLT gives way to an altogether different NATO chain of command. And, instead of reporting to SECDEF and the President, CINCEUR/SACEUR reports to the North Atlantic Council and its subordinate Military Council, which are the NATO command authorities.

The NATO North Atlantic Council consists of civilian representatives from all member nations, and the Military Council brings together their top military commanders. The International Military Staff supports these groups when they are in session, and provides staff support for SACEUR. The Supreme Allied Commander, by mutual agreement, is always the American officer who heads EUCOM.

To command the Sixth Fleet as a NATO force, SACEUR/CINCEUR must pass his orders to the Commander, Allied Forces Southern Europe, a four-star U.S. admiral based in Naples, who then passes them on to COMSIXTHFLT. CINCUSNAVEUR has no role in the NATO command structure, and the NATO southern commander, although a U.S. admiral, has no role in the U.S. structure. Moreover, in the NATO chain, COMSIXTHFLT himself becomes Commander Allied Naval Forces Southern Europe, in charge of whatever national naval forces other NATO members may assign to him.

The command and control problems posed by the dual U.S./NATO operational chain, and the separate administrative chains for all three U.S. services and a host of European countries, are obviously complex. The NATO problem of effectively controlling a huge, multi-national force has been the subject of considerable study and debate, and is one of the central preoccupations in current attempts to upgrade NATO defenses.

OPERATIONAL COMMAND OF THE FORCES AFLOAT

Below the numbered fleet level, U.S. naval operating units form task forces, task groups, task units, and task elements, as illustrated in Figure 4-4. The task organization brings together the units necessary to accomplish specific objectives. World War II experience has tended to associate the words "task force"

with the concept of a carrier task force. In fact, task forces may consist of aircraft, ships, submarines, or combinations of these platforms. Task forces and their components may be permanent or temporary, depending on their purpose. Their composition may undergo rapid change in order to take full advantage of the mobility and flexibility peculiar to the naval forces that compose them.

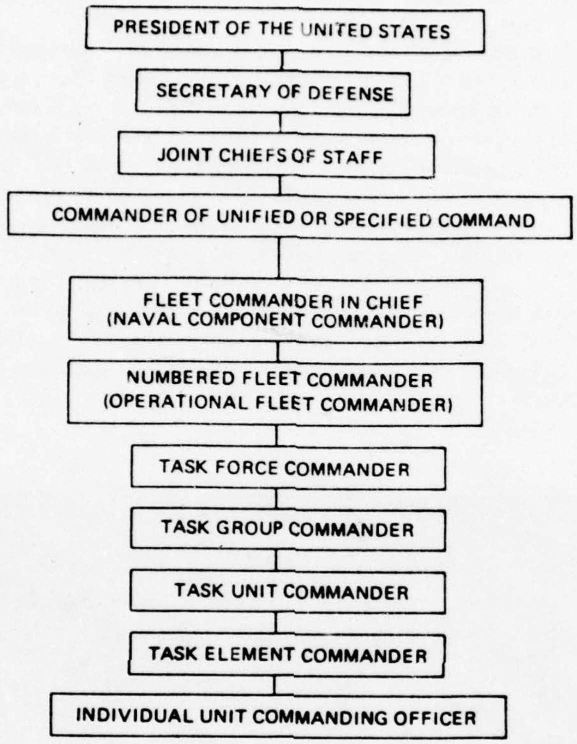

Figure 4-4.
Chain of Command for U.S. Navy Operating Forces.

The operational organization of the U.S. Sixth Fleet provides an example of the groupings that respond to mission requirements. Table 4-1 lists the main functions of the Sixth Fleet numbered task forces.

Table 4-1.
TASK FORCE ORGANIZATION, U.S. SIXTH FLEET

Task Force	Function
60	Battle Force
61	Amphibious Force
62	Landing Force
63	Service Force
64	FBM Submarine Force
66	Area ASW Force
67	Maritime Surveillance and Reconnaissance Force
68	Special Operations Force
69	Attack Submarine Force

The Battle Force Sixth Fleet (TF 60) is the modern equivalent of the World War II "fast carrier task force." The two aircraft carriers that normally form its nucleus constitute Battle Group 1 (TG 60.1), usually commanded by the same officer who commands the entire battle force. The surface combatant screening group (TG 60.5) that operates with the carriers of Battle Group 1 is commanded by the senior surface officer in the force. If COMSIXTHFLT happens to be with the Battle Group, his cruiser flagship is designated a "Special Movement Group" (TG 60.7), so that it can easily be detached from the Battle Group to participate in other operations.

The organization of the Battle Force also provides for a second task group designated Battle Group 2 (TG 60.2) with forces "as assigned." Organizational structures such as this are common throughout the operational organization of the Navy. Their purpose is to supply a ready framework within which to organize available forces as circumstances dictate. For example, if a third carrier and its escorts join the Battle Force but continue to operate at some distance from the other carriers, their commander becomes the commander of Battle Group 2, with a clear relationship to the Commander, Battle Force. If the Battle Force commander decides to split his command into two units, each organized around a single carrier, he can take personal charge of one group as Commander Battle Group 1 while the next senior officer, usually the commander of the Screening Group, takes charge of Battle Group 2. The screening responsibility for each group then devolves upon less senior surface officers designated as commanders of suitably numbered task units. Not all Sixth Fleet task forces are continually in being. But the task force and task group scheme provides for a high degree of flexibility and the rapid establishment of specialized forces to undertake special operations.

Figure 4-5. A large task force of four aircraft carriers, a cruiser flagship, and 12 AAW/ASW escorts maneuvers in close formation in the South China Sea in 1965. The U.S. Navy's flexible task organization allows for a wide variety of force configurations tailored to carry out specific missions.

5
COMMAND AND CONTROL SYSTEMS AND FACILITIES

THE MODERN CONTEXT

The speed and destructiveness of modern weapons systems do not permit delays while decision-makers organize their subordinates and get in touch with the proper superiors. In order to affect the outcome of an operation, "real-time" command decisions must correspond to the rapidly developing conflict situation. The command and control "nodes" that support key decision-makers must maintain efficient and, when necessary, secure communications with other nodes in the chain of command. They must organize and assess a huge amount of data on the operating forces and their environment, providing commanders with concise, real-time information on which to act.

Automated command and control systems, together with long-range communications, enable decision-makers to control events hundreds or thousands of miles away. At present, however, most command and control nodes are only partially automated. While electronic systems have helped to ease the burden of coding and decoding messages; coordinating communications links; and routing, storing, and retrieving data, many other functions that could be automated have tended to remain manual. These functions include taking data from one automated system and entering it in another, handling written messages, switching voice communications, and even manipulating data to produce information (e.g., plotting sequential sighting reports to develop a track for a given target). At many major headquarters, large geographic displays and status boards are still maintained and updated by hand, and voice communications still furnish much of the background information for command decisions.

Command and control facilities currently on the drawing boards or in development seek to replace the current polyglot systems, a patchwork of diverse automated and manual components, with highly automated nodes conceived and designed as integrated units. Moreover, programs now underway are attempting to apply this integrated system design philosophy to the overall integration of many single-purpose nodes that have sprung up over the years. The goal of these large-scale integration efforts is to provide a unified, rational, and flexible structure for all military command and control.

THE NATIONAL SYSTEM

A simplified version of the structural relation between the U.S. national C^3 organization and the Navy Command and Control System (NCCS) is shown in Figure 5-1. At the highest level is the World Wide Military Command and Control System (WWMCCS), which ties together the National Command Authority (NCA), the Unified Commands, and the headquarters of component commanders and service chiefs. Below that level is the Navy Command and Control System, which supports the naval component commanders, the numbered fleet commanders, shore-based headquarters for submarines and ASW aircraft, and Officers in Tactical Command (OTCs) of major forces afloat. At present, the term NCCS is a general designator for all the existing Navy command and control systems at this level, and does not indicate an integrated system. However, this is one of the areas in which large-scale integration efforts are currently underway. Finally, at the lowest level in the command and control chain are the Combat Direction Systems (CDS), which coordinate actual ship and aircraft combat systems.

The command and control nodes designed for various levels of decision-making appear on the right of Figure 5-1. The National Military Command System (NMCS) supports the NCA. Its principal node is

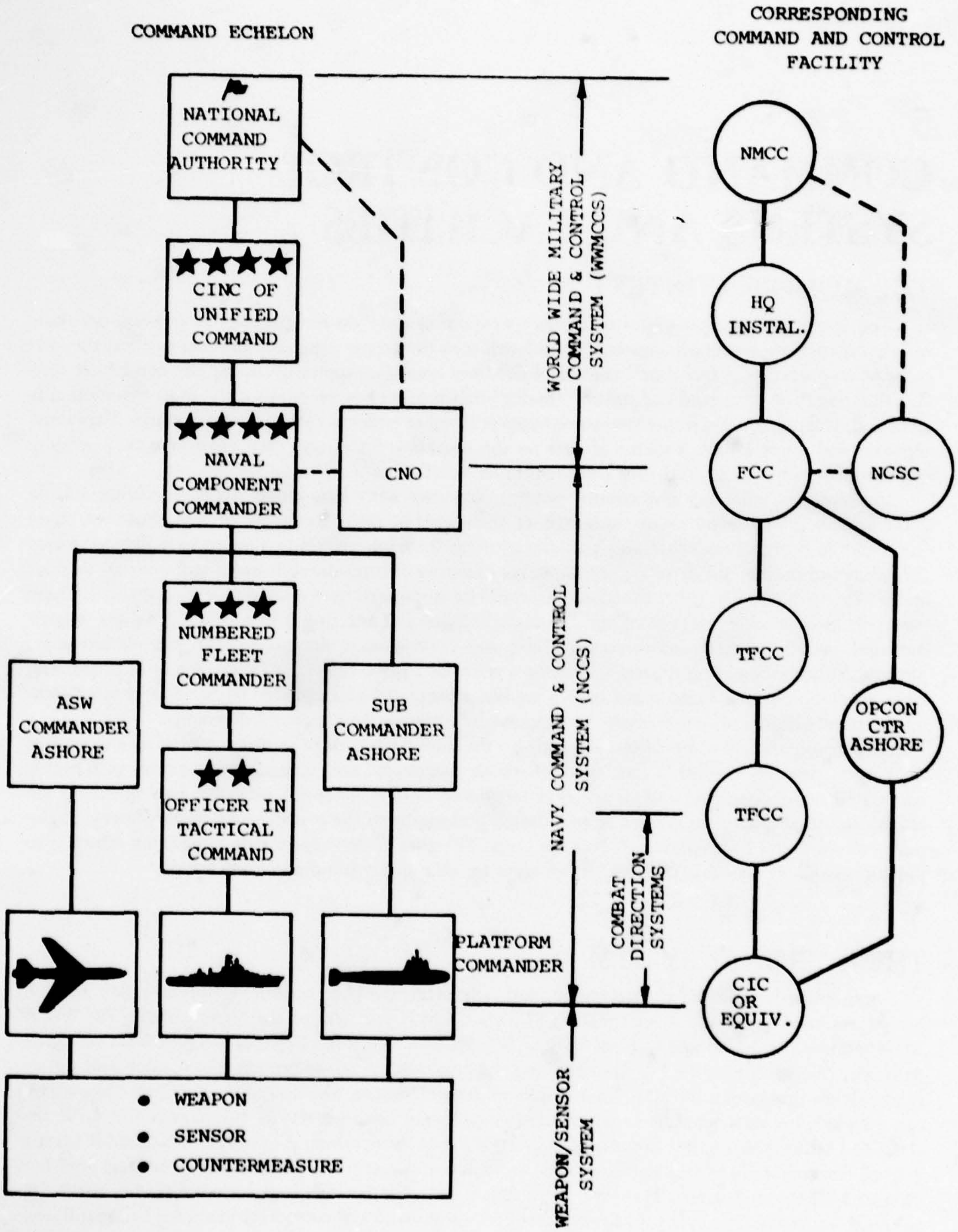

Figure 5-1.
Organization of the Navy Command and Control System.

the National Military Command Center (NMCC) in the Pentagon. To assure the survivability of NCA in a nuclear war, the National Military Command System also includes two standby nodes: the Alternate National Military Command Center (ANMCC), located at Fort Ritchie, Maryland, and the National Emergency Airborne Command Post (NEACP), which is available in specially configured Boeing transport aircraft operating from Andrews Air Force Base near Washington. The NMCC and the ANMCC are hardened against nuclear attack. The NEACP, on the other hand, depends on mobility for survivability. An on-going program to upgrade the command and control nodes of the NMCS has recently doubled the Pentagon floor space alloted to the NMCC and provided large Boeing 747s with elaborate C^3 facilities to serve as NEACP aircraft.

The command and control nodes of the NMCS and the data handling and communications systems that tie them to U.S. military commanders at home and abroad constitute the WWMCCS. The WWMCCS functions by means of landlines, underwater cables, point-to-point microwave, HF, and satellite links. It emphasizes strategic early warning and real-time command and control during crisis situations. Redundancies included in the WWMCCS strategic net provide what is known as the Minimum Essential Emergency Communications Network (MEECN), designed to survive a nuclear first strike. Post-attack command and control systems ensure continuity of command in the aftermath of a nuclear exchange. All of these systems include redundant links to the Navy shore-based command and control facilities for strategic submarines.

The WWMCCS crisis management capability includes direct, secure voice and data links to the major domestic and overseas commands. The heart of the crisis management system is the Defense Satellite Communications System (DSCS), which provides SHF links to special ground terminals at distant locations. Approximately 50 of these terminals connect NCA to major U.S. commanders. Mobile ground terminals in development will permit NCA to talk directly to lower level commanders at the scene of the crisis. DSCS plans call for the installation of terminals only in major Navy flagships. Other ships reporting to NCA during a crisis will continue to do so through the Navy Command and Control System.

The thorough redesign of the WWMCCS that began in the early 1970s attempted to make it a dedicated NCA data support system using "interactive computers" at widely separated locations to provide a "distributed data base." In other words, the WWMCCS would give NCA all the information required for crisis management without lengthy and cumbersome consultations with several echelons of military decision-makers. The system's computers would automatically select the most efficient communication links to handle a particular crisis. They would simultaneously retrieve all of the required background information from various data banks and present it in a useable format.

This aspect of the WWMCCS has proven to be the least successful. Decision-makers facing actual crisis situations have found that the system was limited in capability to set up quickly the required communications net. Instead, patchwork arrangements relying to a great degree on the networks of individual military services had to provide the necessary communications. Furthermore, WWMCCS computers could not come up with pertinent information to support the NCA decision-makers, who found themselves relying on incomplete data gathered on an *ad hoc* basis by their military subordinates.

These problems notwithstanding, WWMCCS represents a significant attempt at building a large-scale, highly flexible system that will certainly become more common as the demand for information and the ability to organize and deliver it continue to develop. As such, it has set the pace for other attempts to restructure command and control systems on the basis of rational design principles and overall system goals.

NAVY COMMAND AND CONTROL SYSTEM

The afloat and ashore command and control nodes that constitute the present NCCS are the product of many years of piecemeal development. The tendency until recently has been to produce single-purpose automated systems to meet specific demands. The Aircraft Carrier Intelligence Center (CV-IC), which actually supports only one kind of aircraft in one kind of mission, is a case in point. On the other hand, higher-level, multi-purpose components such as the existing flag plots afloat are not sufficiently automated to function as real-time command and control nodes. Thus, the NCCS that exists today is a loose confederation of relatively autonomous command and control nodes.

The NCCS development program, begun in the mid-1970s, shared the central goal of the earlier WWMCCS program: to develop a responsive but flexible system subordinating the goals of individual components to those of the larger organization. But the NCCS program differs from the WWMCCS program in several key respects. The NCCS attempts to take full advantage of sophisticated systems that already exist within the Navy command structure. Many nodes will change relatively little as a result of the overall integration effort, and much present equipment will remain standard. The NCCS program also differs from the WWMCCS program in not envisioning radical changes in present command relationships. On the contrary, the thrust of NCCS improvements is to pay more attention to existing relationships by redesigning individual nodes to improve overall system performance.

The most important new command and control nodes of the NCCS are the Fleet Command Centers (FCC), the Tactical Flag Command Centers (TFCC), and the OPerational CONtrol (OPCON) Centers. These new nodes will serve the same command echelons as existing installations, which they are designed to replace. Thus, the FCCs will correspond to the shore-based installations now serving U.S. fleet commanders, the TFCCs will correspond to existing flag plots afloat, and the OPCON Centers will correspond to current shore facilities serving major ASW and submarine commanders. The new nodes will differ from those they replace primarily in terms of their processing capacity and the speed and clarity of their data presentations.

FLEET COMMAND CENTERS

The Fleet Command Center is the principal shore node in the upgraded NCCS, and is designed to support the naval component commanders in each Unified Command. Current plans call for installation of FCCs at Norfolk (CINCLANT/CINCLANTFLT), Pearl Harbor (CINCPACFLT), and probably at the London headquarters of CINCUSNAVEUR. An FCC installation at Naples may also be desirable to support COMSIXTHFLT in his NATO capacity as Commander, Allied Naval Forces Southern Europe.

Another installation that will be reconfigured as a Fleet Command Center is the Naval Command Center (NCC), formerly the Naval Command Support Center (NCSC), in the Pentagon. Known for many years as the Navy "flag plot," NCC provides operational command facilities for the Chief of Naval Operations and designated subordinates. Two considerations make it necessary for the CNO to have such facilities, despite his non-operational role in the official chain of command. First, if the Secretary of Defense does not wish to manage a particular operation through the fleet commander in that area, he has the statutory authority to place the CNO in direct command. For example, the CNO exercised personal control of the U.S. naval blockade during the 1962 Cuban missile crisis. Second, even if he remains outside the operational chain of command, the CNO's broad support responsibilities call for an ability to monitor on-going operations. Thus, he can anticipate the administrative and logistic requirements of a busy fleet commander before that officer has time to make a formal request.

FCCs at the fleet command level will be the primary point of contact between the WWMCCS and the forces afloat. FCC design, therefore, must provide for commonality with WWMCCS hardware and software components. Each FCC will be in contact via the WWMCCS with the headquarters of the Unified Commander in its theater and with the primary nodes of the National Military Command System. The FCC will simultaneously be in direct contact with other FCCs and with the Naval Command Center in Washington via the Navy Command and Control System. While primarily operational in character, the FCCs will also be able to handle some administrative functions in order to relieve the workload of commanders afloat.

Physically, the FCC installation will resemble a highly automated version of the operations rooms pioneered by the British in World War II. Duty officers at a number of consoles on the main floor will receive, process, and analyze incoming data in their areas of interest. Each of the consoles will have small displays that can present this data in both alphanumeric and graphic formats. A senior coordinator will oversee the activities of the watch officers as well as those of personnel assigned to communications and other support stations on the floor. A display controller at his own console will select whatever information is required from the small console displays and transfer it to the large screen displays on the front wall. The principal decision-makers occupy a balcony facing the large displays, and can communicate with operators on the floor by voice intercom. Thus, the decision-makers can request operators to obtain and

display specific pieces of information, and, if necessary, can order the operators to set up direct voice links to distant commands.

The FCC is the focal point for data and information from many sources. The principal source for ocean surveillance information is the Fleet Ocean Surveillance Information Center (FOSIC) at the headquarters of each naval component commander. The FOSICs at Pearl Harbor, Norfolk, and London receive processed information from the Naval Ocean Surveillance Information Center (NOSIC) at Suitland, Maryland, and from deployed reconnaissance and surveillance elements. NOSIC is a general clearinghouse that correlates and screens air, surface, and submarine surveillance data gathered from the Navy's underwater Sound Surveillance System (SOSUS), reconnaissance aircraft and satellites, sighting reports, merchant ship position reports, Lloyds of London, the Defense Intelligence Agency, and other sources. The NOSIC information supplements the direct surveillance data that reaches the FCC from the component command's own assets, including forward-based Fleet Ocean Surveillance Information Facilities (FOSIF), at Rota, Spain, and in the Western Pacific, and ASW Force OPCON Centers, which control land-based ASW and patrol aircraft.

Redundant communications channels and high-speed data transmission have led to an "explosion" of data and information moving through the NCCS. Almost every major node in the system "talks" directly or indirectly to every other node. For this reason, a major goal of NCCS modernization is to simplify these exchanges along functional lines and eliminate unnecessary contacts. The FCC's ability to serve as the focal point for both information exchange and fleet command and control will bring NCCS much closer to this goal.

The FCC's main function is to permit the shore-based commander to allocate and reallocate his operational resources over a broad geographic area. This calls for constant evaluation of inputs from a great number and variety of sources. Only a shore location can provide the automated data processing and display capacity necessary to screen and evaluate all these inputs on a real-time basis while responding to the information requirements of subordinate commanders and providing the information for a host of high-level decisions affecting the theater as a whole.

Supporting the tactical commander afloat is almost as important a function for the FCC as the proper allocation of theater resources. Current shore installations have only a limited ability to support tactical operations. The FCC, in contrast, will not only relieve shipboard personnel of many reporting and liaison responsibilities, but will actually supply real-time tactical information to the commander afloat.

The unprecedented capabilities of the FCC will give the shore-based naval commander a greater role in tactical operations than ever before, but they will not in any way diminish the command and control functions of the commander of the task forces, groups, and elements that make up the forces afloat.

COMMAND AND CONTROL AFLOAT

Since the retirement of the two National Emergency Command Post ships in 1970, the most extensive U.S. naval command and control nodes afloat have been in the obsolescent missile cruisers serving as fleet flagships, and in the two amphibious command ships (LCC) designed to coordinate major amphibious landings. The only other U.S. naval combatants with accommodations for the commander of a fleet or large task force are the 11 large-deck carriers built since World War II. The two LCCs have now replaced retiring cruiser flagships in the Second and Seventh Fleets, but some additional command duties will also fall on the already overworked carrier C^3 nodes. Like current shore nodes, these carrier installations are at present made up of many single-purpose systems, each designed to do a specific job, but generally not conceived as part of a unified system. The piecemeal addition of components over the years has tended to make the entire installation "input-output bound," i.e., glutted by its own data flow. At the same time, elements and interfaces within the CV node represent different degrees of automation, the flag plot itself being one of the least automated command and control spaces in the ship.

Generally, the elements that make up command and control nodes afloat fall into two broad categories. The first category consists of broad-area surveillance systems, like CV-IC and SSES, and high-level command and control installations, such as the flag plots and flag display and decision spaces in the Combat Information Centers. The latter assist the force commander to allocate and dispose his units in the best way to achieve the tactical objectives of the force.

The secondary category of command and control elements consists of Combat Direction Systems (CDS) which coordinate force and/or own-ship combat systems in the actual engagement of enemy units. Typical Combat Direction Systems are the Naval Tactical Data System (NTDS) and the Aircraft Carrier Tactical Support Center (CV-TSC). Inevitably, there is a good deal of overlap between combat direction and higher-level command functions. For instance, the Combat Information Center, whose functional core is NTDS, supplies data on the local situation both to the officers in charge of combat systems and to the force commander.

TACTICAL FLAG COMMAND CENTER

To free the higher command function from existing restrictions, efforts are now underway to develop a flag space with dedicated automatic data processing (ADP) and display systems. This installation is known as the Tactical Flag Command Center (TFCC). The task of designing the TFCC within the constraints imposed by available flag spaces is difficult, and has encountered a great many technical and cost obstacles. Nevertheless, compact ADP and display components may now provide the means to overcome these obstacles. Without such installations, high-level commanders of forces at sea will risk becoming more and more isolated from the increasing pace and scope of naval combat. Therefore, development of the CV-TFCC has proceeded in spite of the obstacles, and, if successful, will lead to the installation of similar facilities in modern missile cruisers (CG-TFCC) and in certain amphibious ships (LCC/LHA-TFCC).

The TFCC will be the principal afloat node in NCCS, the counterpart of the FCC for fleet, task force, and task group commanders afloat. The TFCC compensates for shipboard space constraints by taking maximum advantage of the shore-based FCC's superior source correlation and data processing capabilities. The FCC will supply the TFCC with pertinent regional information such as ocean surveillance

Figure 5-2. Specially converted World War II cruisers, such as the Springfield *(CG-7), shown here in Gaeta, Italy, served as flagships of U.S. numbered fleets from the early 1960s until the late 1970s.*

reports, threat summaries, environmental data, mission support information, and special alerts. The FCC will even provide the TFCC with specific tactical data such as intelligence on the status and capabilities of enemy combat systems and the location and identification of over-the-horizon targets.

Thus, the TFCC will give the flag commander access to much broader information than he now receives, and will, at the same time, give him sufficient ADP to receive, interpret, and employ operational data from own-ship and own-force surveillance and combat direction systems. Like current display and decision spaces, the TFCC will be able to rely on own-ship sensors for data on the local situation and, through NTDS, will receive sensor inputs from other platforms as well. The decision-maker will use the TFCC facilities to identify and choose among alternative courses of action, to assess the effectiveness of his own decisions, and to delegate time-sensitive responsibilities to subordinate commanders. In crisis situations, he may also use them to respond directly to NCA, a contingency provided for in the TFCC design.

ELEMENTS WITHIN THE CARRIER COMMAND AND CONTROL NODE

The principal tactical surveillance centers in the aircraft carrier command and control nodes are the Ships Signal Exploitation Space (SSES) and the Aircraft Carrier Intelligence Center. The CIC can be considered as a surveillance installation as well, since it receives all own-ship sensor data plus a considerable amount of data from other own-force sensors. But the CIC's close identification with NTDS makes it possible to regard it as primarily a combat direction system. As this indicates, there is a great deal of overlap between the two functions.

For obvious reasons, there is little unclassified information concerning the SSES. To appreciate the importance of this center, as opposed to its exact workings, it is only necessary to realize the vital role that electronic support, countermeasures, and counter-countermeasures play in modern combat. The SSES gathers and processes the electronic intelligence data that makes U.S. Navy electronic warfare effective.

The CV-IC was developed to support the RA-5C Vigilante reconnaissance aircraft, and has extensive facilities for integrating, analyzing, and transmitting photographic reconnaissance data. The CV-IC supports the carrier's capability to project power ashore by identifying prospective targets, pinpointing enemy AAW defenses, assessing battle damage, and performing other services that only photographic reconnaissance can accomplish.

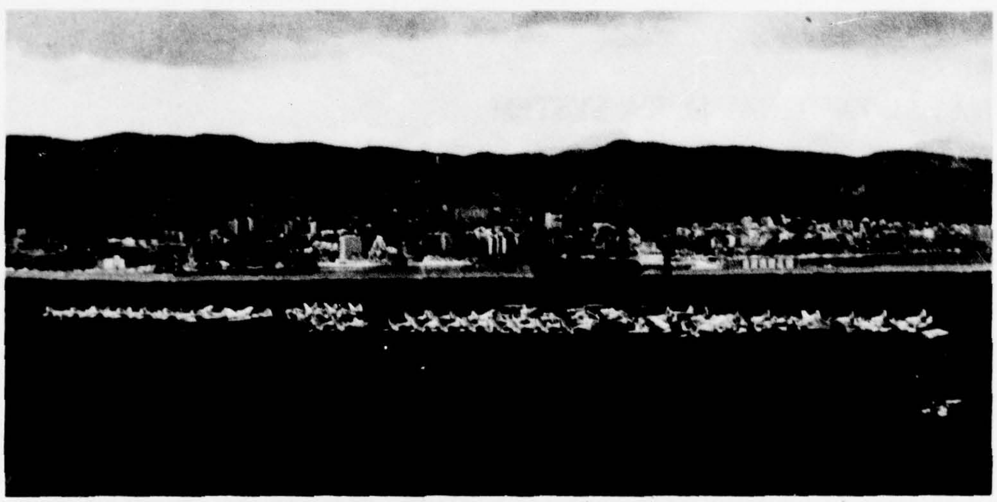

Figure 5-3. The complex command and control requirements of large-deck aircraft carriers make them a major focus of C^3 development efforts. In addition to supporting her commanding officer, controlling local air traffic, and coordinating offensive and defensive operations of the air wing, a carrier such as the John F. Kennedy *(CV-67) may be called upon to support a task force commander and his staff.*

Figure 5-4. An aircraft carrier's CIC, a small portion of which is shown here, is a crucial command and control space that determines how effectively her combat systems will respond to a coordinated threat.

NAVAL TACTICAL DATA SYSTEM

The most important of the combat direction systems is the Naval Tactical Data System. NTDS is standard equipment in most large surface combatants and several amphibious ships. An austere installation in the E-2C aircraft, called the Airborne Tactical Data System (ATDS), is used for controlling carrier-based fighters and other aircraft. Additional NTDS installations are currently planned for smaller ships such as frigates (FF/FFG) and older missile destroyers.

NTDS was originally designed in the late 1950s to coordinate own-ship and own-force weapons and sensors against high-speed jet aircraft. The NTDS computers could correlate highly perishable threat and weapon status data much more rapidly than by hand, and could exchange that information "computer to computer" via high-speed data links between ships. NTDS has undergone a series of modifications since its inception 20 years ago as a purely air defense system, but its basic operating philosophy has remained the same, and it still calls for a great many manual inputs and manual interfaces between automated systems.

NTDS operators manning detector/tracker consoles feed data on radar contacts into the system's computers. Console operators continue to update the contact position until the computer has enough data to begin smooth tracking automatically. The computer then marks the target by superimposing appropriate symbols at its position on the radar PPI display. Meanwhile, ancillary displays indicate target course, speed, altitude and composition. When the operator determines that the contact is hostile, he

indicates this by altering the symbology displayed on the PPI scope. If the target alters course or speed, the operator must once again feed in position updates until the computer can resume smooth tracking. Other manual operations are needed to retrieve stored information such as the availability of friendly weapon systems, the fuel status of friendly aircraft, and identification codes. There is a certain amount of human input even for "computer-to-computer" exchanges among platforms.

The NTDS shipboard layout consists of a series of "modules," each concentrating on a specific function such as air operations or electronic countermeasures. Modularity allows operators with similar responsibilities to work together. It helps to solve shipboard space problems by permitting greater flexibility in the arrangement of the modules. Although some modules are specialized for a given platform, others perform functions common to many platforms, thereby achieving the maximum possible standardization among installations. Interactive display systems ease the transfer of information from one module to another, and from all modules to the commanding officer's CIC station and, in flagships, the force commander's display space.

In spite of the persistence of manual functions in NTDS installations, the trend is clearly towards increased automation. The introduction of Link 4A (see Chapter 6) gave NTDS operators in ships and specially equipped aircraft a way to exercise positive control over defensive aircraft, literally "flying" interceptors to their targets without the need for active pilot participation. Improved commonality of link and message standards with other services and with NATO allies has resulted in the replacement of cumbersome voice links with direct data links for joint operations. Previously non-automated warfare areas like ASW have recently begun to make new demands on the automatic data processing capabilities of NTDS, and later models have sought to automate these functions within the existing framework.

The latest version of NTDS -- Model IV -- has a larger data processing capacity than the previous Model III, and covers a larger number of functional areas. Automation of ASW sensor and weapon coordination, especially in surface combatants, has progressed significantly, including processing and display systems for sonobuoy data relayed to the ship by ASW helicopters. Electronic warfare and anti-ship missile defense are two other areas that also show marked improvement. Perhaps the greatest single advance, however, is in the system's original field of concentration: air target acquisition and tracking. Model IV's Automatic Detection and Tracking (ADT) system has reduced human input to the identification of contacts and the initiation of automatic tracks. In the process, it has improved the quality of NTDS tracks and the speed with which they can be initiated.

ASW TACTICAL SUPPORT CENTERS

Although NTDS is by far the most important combat direction system in U.S. Navy ships, an ASW system in aircraft carriers also deserves attention. The Aircraft Carrier Tactical Support Center (CV-TSC), like the carrier intelligence center, was developed to interface with a specific aircraft, in this case, the S-3A Viking. The S-3/TSC combination has helped to make the large-deck carrier one of the most effective ASW platforms in the U.S. fleet, thereby compensating in part for the earlier retirement of the specialized ASW carriers (CVS). The CV-TSC, scheduled to be installed in all active aircraft carriers by 1979, is similar in design and function to the Patrol Aircraft Tactical Support Centers (VP-TSC) located at P-3C bases ashore. It serves as a clearinghouse for ASW information and provides preflight briefing material and direct inputs to the aircraft's on-board computers. After a flight, the CV-TSC analyzes the sensor data collected by the aircraft, and uses it to update the overall ASW picture for reallocating anti-submarine assets.

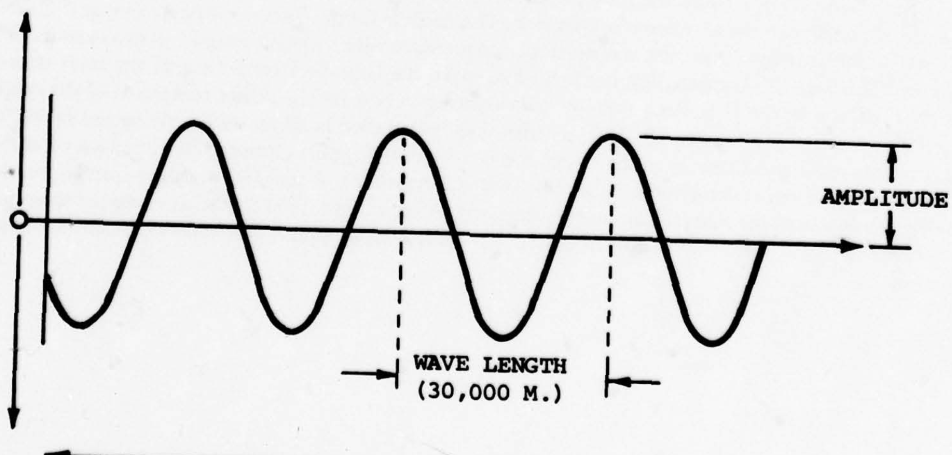

Figure 6-1.
Wavelength and Amplitude of a Radio Wave.

6
NAVAL COMMUNICATIONS

GOALS

Naval communications link the naval command hierarchy to the operating forces ashore, at sea, and in the air. Communications are the "nerves" of the Navy, carrying command and control information to units of the fleet and vital feedback on friendly and hostile forces to higher levels of command. Communications also extend laterally among units of the operating forces, enabling them to keep one another informed and to assist one another in the performance of complex and demanding missions. Finally, communications tie operational units to the Navy's massive logistics structure, enabling support forces to respond rapidly to the needs of the fleet.

Naval communications are organized in a complex network, the essential attributes of which are reliability, speed, and security. Reliability comes from systematic procedures, modern equipment, and redundant message paths. Speed is provided by efficient processing systems, up-to-date transmitting, receiving and relay equipment, and standard message formats. Security comes from automatic encryption systems and carefully controlled transmitting procedures.

The communications that make up the Navy network take many forms. Long-range broadcasts originating at major command installations ashore and afloat keep the fleet apprised of important operational and administrative developments and provide a one-way path for promulgating command decisions. Long- and short-range ship-to-ship and ship-to-shore links provide the information exchange needed to coordinate the movements of individual fleet units and formations. Computerized combat direction systems in ships and aircraft exchange vital sensor and fire control information via a number of high-speed data links. Tactical radio-telephone systems back up these high-speed links, providing an extra measure of flexibility at the tactical level.

Efficient and effective communications are an essential prerequisite of modern naval operations. In an era of high-speed, long-range weapons, an increasing threat from hostile naval forces, and declining U.S. Navy force levels, the U.S. Navy's ability to fight immediately and effectively has never been more important. First-rate communications are a vital part of this capability.

RADIO FREQUENCY SPECTRUM

Radio signals propagate in electromagnetic waves, which can be compared to ripples radiating from the spot where a stone is dropped in a pond. All electromagnetic waves radiate from the point of origin at approximately 186,000 miles (300,000,000 meters) per second, i.e., the speed of light. While all electromagnetic waves travel at the same speed, they differ very significantly in ***wavelength*** (the physical distance from a given point in one wave to the corresponding point in the next) and in ***amplitude*** (the "height" or strength of each wave crest).

One complete wave motion is called a *cycle*. Since all electromagnetic waves travel at roughly the same speed, the length of the wave determines how long it will take one complete wave cycle to pass a given point in space. The 30,000-meter wavelength shown in Figure 6-1, for example, takes about .0001 seconds to complete one cycle. This means that 10,000 cycles pass a given point during each second, hence ten thousand cycles per second is the *frequency*.

Frequency is measured in ***hertz*** (abbreviated Hz), a term chosen to honor Heinrich Hertz, the discoverer of the radio wave phenomenon. A hertz is simply a measure of cycles per second. The wave in Figure 6-1 has a frequency of 10,000 cycles per second, or 10,000 Hz. For convenience, frequencies in thousands, millions, and billions of hertz are expressed by using standard prefixes: one thousand hertz

equal one kilohertz (KHz); one million hertz equal one megahertz (MHz); and one billion hertz equal one gigahertz (GHz).

Radio signals, of course, are merely one type of electromagnetic wave. Others include the infrared, visible, and ultra-violet forms of light, X-rays, and Gamma-rays. The characteristics of each type of electromagnetic radiation depend on the frequency of the wave. Frequency ranges that have certain characteristics in common are called frequency *bands*. Electromagnetic frequencies higher than three billion gigahertz (3×10^{18} Hz) take the form of Gamma-rays or X-rays. The band of frequencies between three hundred and three billion gigahertz ($3 \times 10^{11} - 3 \times 10^{18}$Hz) occur as infrared, visible, or ultraviolet light. The relatively narrow range of frequencies below 300 gigahertz, which occur as radio waves, form what is known as the Radio Frequency (RF) band.

Since electromagnetic waves within the RF band travel in different patterns according to their frequency, they offer potential users a wide choice of communication paths. Certain radio waves will even follow the curvature of the earth for thousands of miles. Although a good deal narrower than the light bands, the RF band nevertheless spans nearly 300 billion hertz, and provides a sufficient range of frequencies, with proper allocation, to meet most of today's communications demands. Projected increases in those demands, coupled with advances in electro-optics, are now encouraging greater exploitation of the higher light bands, but the technology for doing so is still relatively new, and the RF band probably will continue to carry most non-landline traffic for at least the next two decades.

As discussed above, the characteristics of different frequency groups within the RF band itself vary considerably. For example, the Extremely Low Frequency (ELF) waves below 300 Hz can easily penetrate dense seawater, whereas the Extremely High Frequency (EHF) waves above 30 GHz have difficulty penetrating a heavy rainstorm. For convenience, therefore, the RF band is divided into a number of smaller bands, each with its own distinct characteristics. Although the exact demarcations between bands are necessarily arbitrary, with considerable overlap between nearby frequencies of different bands, the differences which these band designations highlight are sufficiently important to merit consideration in the design and operation of C^3 systems. Table 6-1 shows the principal RF bands, as well as some of their more important characteristics and their principal uses in the U.S. Navy communication system.

DATA RATE

One of the most important differences between radio bands is their data rate: the amount of intelligence they can transmit in a given amount of time. Generally, the higher the frequency the greater the data rate. Many complex factors enter into this relationship, but the underlying principle is relatively simple. A radio wave of constant amplitude and frequency tells the receiver only that someone is transmitting. In order to increase the flow of information to a meaningful level, it is necessary to vary the signal in some way. Two standard methods for doing so are *Amplitude Modulation* (AM) and *Frequency Modulation* (FM). AM varies the amplitude of the signal while holding the frequency constant; FM varies the frequency while holding the amplitude constant.

Both AM and FM signals express their information content largely in terms of the differences between one wave cycle and the next. In AM the amplitude of one cycle may be more or less than that of its predecessor, whereas in FM the wavelength may be longer or shorter. Changes from one cycle to the next can signify anything from variations in the tone of a musical instrument to points on a curve, depending on the encoding and decoding of the information. Since each wave cycle carries a limited fragment of intelligence, the data rate depends, to a considerable extent, on how fast succeeding wave cycles arrive at the receiver. A frequency of 10 kilohertz means that ten thousand data-laden wave cycles arrive at the receiver in each second of time; a frequency of 10 megahertz means that ten *million* cycles will arrive during the same period. Assuming that each wave cycle carries the same amount of data in both cases, the potential data rate of the 10 megahertz signal will be 1,000 times greater than that of the 10 kilohertz signal.

Frequency is not the only factor affecting the data rate of radio signals. The power of the signal and the amount of interference it must overcome are particularly important in determining the potential data rate of an AM signal, since they determine the range of amplitude variations available for conveying information. AM signals, as a rule, use a smaller range of frequencies than FM signals for conveying a given

Table 6-1.
Characteristics and Navy Uses of Frequency Bands.

BAND	FREQUENCY RANGE	PRIMARY PROPAGATION PATHS	RELATIVE INTELLIGENCE CAPACITY (ELF ≈ ~1)	PRINCIPAL U.S. NAVY COMMUNICATIONS FUNCTION(S)	U.S. NAVY COMMUNICATIONS MODE(S)
EXTREMELY LOW FREQUENCY (ELF)	30-300 Hz	Earth-ionosphere duct Surface wave Water path	1	Experimental submarine broadcast	--
VERY LOW FREQUENCY (VLF)	3-30 KHz	Earth-ionosphere duct Surface wave Water path	10^2	Submarine broadcast	Teletype
LOW FREQUENCY (LF)	30-300 KHz	Surface wave	10^3	Fleet and submarine broadcast	Teletype
MEDIUM FREQUENCY (MF)	300 KHz-3 MHz	Surface wave	10^4	Fleet, submarine, and ship-to-ship broadcast Ship-to-ship, ship-shore-ship High priority, long-range voice CW backup	Teletype Limited voice Limited telegraph
HIGH FREQUENCY (HF)	3-30 MHz	Sky wave Surface wave Line-of-sight	10^5	Fleet, submarine, and ship-to-ship broadcast Ship-to-ship, ship-shore-ship Long range tactical voice High priority long range voice NTDS links 11, 14 CW backup	Teletype Voice Digital Data Facsimile Limited telegraph
VERY HIGH FREQUENCY (VHF)	30-300 MHz	Line-of-sight Scatter	10^6	Tactical radio-telephone	Voice
ULTRA-HIGH FREQUENCY (UHF)	300 MHz-3 GHz	Line-of-sight Tropospheric scatter	10^7	Fleet broadcast Short range ship-to-ship, ship-shore-ship Tactical radio-telephone Satellite broadcast NTDS Links 11, 14 NTDS/ATDS LINK 4A	Teletype Voice Digital Data
SUPER HIGH FREQUENCY (SHF)	3-30 GHz	Line-of-sight	10^8	High-priority satellite communications with fleet flagships and shore nodes.	Various
EXTREMELY HIGH FREQUENCY (EHF)	30-300 GHz	Line-of-sight	10^9	Experimental satellite communications	--

amount of data, since their information content does not depend on movement from one frequency to another. Techniques which affect the way electromagnetic energy is spread across a range of frequencies (e.g., *single side band, spread spectrum*) also have an important effect on the potential amount of data that can be transmitted in a given frequency range.

Such factors, however, can only modify the basic relationship between frequency and data rate. All else being equal, higher frequencies can carry more data than lower frequencies in a given period of time. This is the major reason that most Navy communications, particularly the high-volume radio-telephone channels and high-speed tactical data links (e.g., NTDS Links 11, 14, and 4A), use the HF band and above. Greater potential data rates also provide more opportunities for increasing redundancy and employing a variety of manipulative techniques intended to increase message security and decrease the vulnerability to enemy jamming. This is one major attraction of the Ultra-High Frequency (UHF) and Super High Frequency (SHF) bands used in satellite communications.

SIGNAL PROPAGATION

In addition to data rate, one of the most important characteristics for any frequency band is the path which waves in those frequencies tend to follow after leaving the transmission station. Radio waves tend, as a rule, to propagate uniformly in all directions. However, this tendency is overshadowed in many frequency bands by certain ***propagation paths,*** which waves of a given frequency can follow with greater ease.

The primary propagation paths shown in Table 6-1 do not include all of the paths that waves in each band can follow. Moreover, the arbitrarily sharp distinction between bands obscures the fact that wave characteristics change gradually and continuously across the frequency spectrum. Nevertheless, the propagation paths shown in each case are the dominant ones for each band, and are instrumental in determining its primary uses.

Radio waves in the four lowest frequency bands propagate mainly by what is known as the surface, or ground wave. This means that they propagate with the least loss of power ***(attenuation)*** when following the curvature of the earth. Their tendency to follow the earth's curvature for relatively long distances is very useful for communications between shore installations and distant mobile units, such as ships and submarines.

Surface wave propagation below 1.5 MHz is stable, reliable, and limited mostly by man-made or atmospheric interference. Surface waves are only moderately affected by the atmospheric side-effects of nuclear weapons or by normal disturbances in the upper atmosphere and the earth's magnetic field. They are therefore ideal for signals such as fleet and submarine broadcasts, which must be transmitted either continuously or at very regular intervals. As a rule, such broadcasts do not require a high data rate.

The Very Low Frequency (VLF) and Extremely Low Frequency (ELF) bands are particularly advantageous for broadcasting to submerged submarines. At those frequencies, the wavelength is so long that the entire atmosphere serves as a giant waveguide and -- like a huge cable -- channels the wave, carrying it with little attenuation for thousands of miles. These long-range signals are then channeled downward through the ocean's surface to submerged submarines.

The most significant propagation path for the High Frequency (HF) band is the so-called ***sky wave.*** HF transmissions propagate in more of a straight line than transmissions at lower frequencies, and they do not conform nearly as well to the curvature of the earth. This would limit the normal range of many HF frequencies to a little beyond the visual horizon were it not for the charged particles in the ionosphere (25-250 miles above the earth) that reflect and refract (bend) HF radio waves. The reflection and refraction of HF signals from the ionosphere back towards the earth extend their range far beyond the visual horizon, as illustrated in Figure 6-2.

A sufficiently strong HF signal will make repeated hops that can carry it thousands of miles from the transmitter. One undesirable side effect of the sky wave, however, is the existence of a skip zone between the maximum surface wave range and the minimum range at which signals bounce back to earth. Moving ships and aircraft frequently pass through HF skip zones, and HF systems must attempt to overcome this disadvantage by operating numerous transmitters carefully located to provide overlapping coverage in major operating areas.

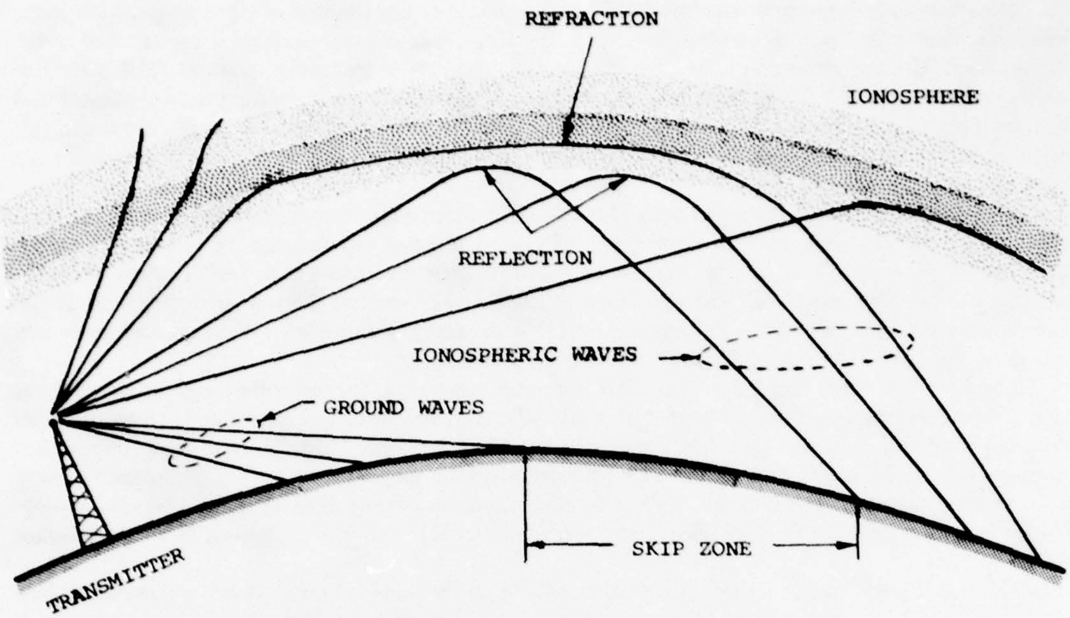

Figure 6-2.
Reflection and Refraction of Radio Waves in the HF band.

The sky wave propagation path is also unusually susceptible to disturbances in the upper atmosphere. Sunspot activity, electromagnetic storms, and other natural phenomena can severely disrupt HF traffic, as can high-altitude nuclear explosions and enemy jammers hundreds or even thousands of miles from the intended receiver. As a result, HF is not well suited for command and control functions requiring highly reliable communications, but this does not detract from the usefulness of this band to meet other long-range communication requirements.

Above the HF band are the Very High Frequency (VHF) and Ultra High Frequency (UHF) bands. VHF extends from 30 to 300 MHz, and UHF from 300 MHz to 3 GHz. These bands propagate primarily by line-of-sight, which limits their range to approximately the visual horizon without airborne or satellite relays. Concentrated VHF and UHF beams, however, can achieve greater ranges by utilizing tropospheric and ionospheric scatter.

Tropospheric scatter occurs because of variations in the temperature and humidity of the troposphere, that portion of the atmosphere roughly seven to ten miles above the earth's surface. Variations in the tropospheric air masses bend VHF and UHF waves back toward the earth. In the process, the signal is "scattered," i.e., sent back to earth at a number of angles not necessarily related to the angle of incidence. A sufficiently powerful transmission can carry such a signal up to 400 miles. Tropospheric scatter links can be helpful for filling in the skip zones not covered by normal HF transmissions. Special ionospheric scatter links using the VHF band can achieve a similar effect at higher levels in the earth's atmosphere. The use of ionospheric scatter can result in ranges of 1,000 miles or more.

Like HF communications, scatter links are vulnerable to natural disruptions. Ionospheric scatter links are affected by electromagnetic anomalies, and tropospheric scatter links are subject to disruption by disturbances of the lower atmosphere. Even under the best conditions, successful use of these paths requires relatively high power levels and concentrated, carefully aimed beams of energy. Otherwise, radio waves in the VHF and UHF bands will follow a line of sight path out into space. The relatively large and stable antenna installations required to direct the transmissions properly are more easily provided on land than at sea. Thus, the primary use of ionospheric and tropospheric scatter has been for high-priority communications between fixed shore installations.

Most naval communications in the VHF band and higher use the line-of-sight propagation path, either for short-range tactical communications or for long-range communications using satellite or airborne relays. Because atmospheric interference tends to decrease as frequency increases, VHF and UHF links can be made very reliable. High reliability is a crucial element of quick-reaction tactical communication systems, and radio circuits above 100 MHz compare favorably with wire and cable circuits in this respect. Moreover, line-of-sight transmissions cannot be jammed -- or, as a rule, even detected -- by systems beyond the visual horizon.

Generally, the greatest threats to both VHF and UHF systems are blast damage to antennas and electronic surge effects associated with nuclear detonations. The latter can damage the system's electronic components. The signals themselves experience relatively little disruption even from nuclear weapons, with typical blackout times for UHF signals being less than ten seconds. However, atmospheric disturbances can sometimes cause fluke propagation over long distances to unintended receivers, and heavy rain can cause attenuation in the upper reaches of the UHF band.

The first U.S. Navy employment of UHF communications was for controlling fighter aircraft over task forces and amphibious objective areas in World War II. Airborne early warning and communications relay were added to the list of UHF functions in the late 1940s and early 1950s. Since the first communications satellites were launched in the early 1960s, extremely long range line-of-sight communications have become commonplace. The U.S. Navy Fleet Satellite Communications (FLTSATCOM) system employs this propagation path for fleet broadcasts and for highly reliable two-way communications with distant forces.

The Super High Frequency (SHF) and Extremely High Frequency (EHF) bands have also come into use in recent years to provide reliable long-range satellite communications. Signals in these bands, which extend from three to 30 GHz and from 30 to 300 GHz, respectively, can be formed into very narrow beams by properly configured antennas. Since it is easiest for an enemy to jam a signal from within this main beam, or *lobe*, the narrowness of lobes in the SHF and EHF bands makes optimum placement of enemy jammers much more difficult. If the enemy cannot beam energy directly into the main lobe, he must attempt to jam the weaker beams, known as *sidelobes*, which radiate at an angle from the main lobe. Sidelobe jamming, however, requires much more power.

DEFENSE COMMUNICATIONS SYSTEM

The Defense Communications System (DCS) provides the basic long-distance communications structure for worldwide command and control of U.S. military forces. In general, the DCS manages communications under the WWMCCS and most of the communications of the Navy shore establishment, while the Naval Telecommunications System provides communications under the Navy Command and Control System (see Chapter 5). The DCS is managed by the Defense Communications Agency (DCA).

The DCA was established in 1960 as part of an effort to combine and streamline the long-distance communications systems operated by each of the three services. Today, the DCA manages an overall communications system composed primarily of elements owned, operated, and maintained by the services. The objective of the DCA is to maximize the commonality and interoperability of the present DCS, and to develop a new "second-generation" system designed from the beginning for the greatest degree of interservice commonality and flexibility in both hardware and procedure.

The current, "first-generation" DCS is composed of four principal systems: the Automatic Digital Network (AUTODIN), Automatic Voice Network (AUTOVON), Automatic Secure Voice Communications network (AUTOSEVOCOM), and Defense Satellite Communications System (DSCS). The first three systems can each employ a variety of transmission media, including microwave and long-range radio, land line, undersea cable, and satellite relay. Currently, DCA policy for transoceanic communications calls for the use of a mix of transmission media: one-third of the communications are transmitted via military satellite, one-third via leased commercial satellite, and the remainder via leased undersea cable.

AUTODIN is a DoD-wide system for the transmission of data in digital form. Traffic includes narrative messages, teletype, pictures, and facsimile. AUTODIN provides major commands with command and control information, as well as logistics and administrative communications. AUTODIN was developed from an Air Force data communications net originally designed for service-wide logistics com-

munications. The AUTODIN system has over 1300 tributary stations of all services, with 19 fully automatic switching centers (nine in the U.S. and 10 overseas).

AUTOVON provides direct-dial voice links between shorebased DoD activities via some 86 switching centers in the Continental United States (CONUS), Canada, Hawaii, and overseas. There are more than 2,200 Navy subscribers. Each CONUS and Hawaiian switching center is operated by independent U.S. commercial telephone companies, while the overseas switching centers are operated by the military services. Provision is made in the AUTOVON system for AUTOSEVOCOM.

AUTOSEVOCOM provides secure voice links to about 1500 AUTOVON subscribers. It is a largely manually-controlled net made up of equipment developed and fielded by the Army and Air Force in the mid-1960s. The limited number of subscribers, relatively poor quality of the transmission, and high cost per circuit are significant limitations. The Director, DCA, has stated that the greatest military communications weakness is the lack of a secure voice net that is widely available and easy to use. As an interim improvement, the DCA has established a small number of wideband (satellite-relayed) circuits, which offer greatly improved quality, but at high cost.

The Defense Satellite Communications System currently has three active geo-stationary satellites in the DSCS-II series, and at least one more launch is scheduled for 1979. These 1,365-pound satellites are designed for a life of five years. It was originally planned to have four active satellites plus two spares in orbit, with two satellites being launched every other year. However, the 1975 pair failed to achieve orbit, placing considerable strain on the DCS system as a whole. The DSCS-IIs operate in support of the WWMCCS and relay communications in the SHF band. In Navy command and control terms, this means that the DSCS-IIs can relay messages to the Fleet Command Centers ashore and to the Task Force Command Centers aboard the major flagships. Because of the size and complexity of current SHF receiving terminals, however, few Navy ships other than flagships will be able to communicate directly via these satellites. A new SHF terminal under development may improve the situation.

Figure 6-3. An artist's concept of a geo-stationary satellite in the Defense Satellite Communications System (DSCS) Phase II series. The two "dish" reflectors focus Super High Frequency (SHF) radio waves in narrow beams for improved security and increased resistance to jamming.

The DCA is now engaged in developing and deploying elements of the second-generation DCS. The major features of the second-generation system hinge upon a switch from analog to digital transmission systems and improvements to the AUTODIN, DSCS, and AUTOSEVOCOM systems. The change from analog to digital data transmission will mainly affect DCS voice circuits. The objective of the program is to change analog speech into a digital format, which can be more easily encrypted and which is much more compatible with satellite relay systems. AUTODIN enhancements under the AUTODIN II program will facilitate computer-to-computer data exchange, improve the encryption system, and improve the ability of the AUTODIN network to sort messages of different priorities. The DSCS-III satellites now under development and scheduled for first launch in 1979 have far greater capacity, double the life span, and one hundred times the resistance to jamming possessed by the DSCS-II. AUTOSEVOCOM II is intended to provide a common secure voice network for both civil and military government agencies and should answer the major shortcomings of the present system. It will be able to service some 10,000 subscribers, and will permit secure communications from the AUTOSEVOCOM telephone network through an elaborate switching system to tactical radios in the field.

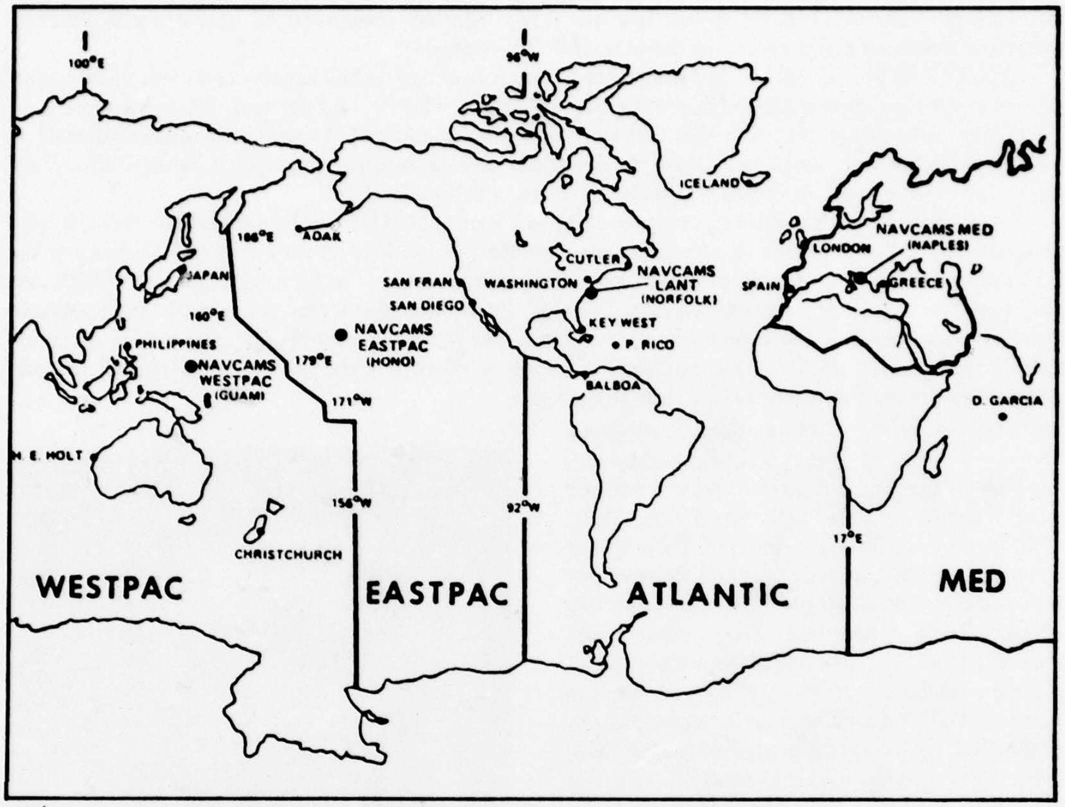

Figure 6-4.
The four Naval Communication Areas of the Naval Telecommunications System (NTS).

NAVAL TELECOMMUNICATIONS SYSTEM

Long-Haul Communications

The Naval Telecommunications System (NTS) operates and maintains a network of Naval Communications Stations (NAVCOMMSTAs) worldwide for the DCS. It controls them via four Naval Communications Area Master Stations (NAVCAMS) in Norfolk, Naples, Honolulu, and Guam. The communications areas controlled by the NAVCAMS correspond roughly to the areas of responsibility of CINCLANTFLT (NAVCAMS Norfolk), CINCUSNAVEUR (NAVCAMS Naples), and CINCPACFLT (NAVCAMS Honolulu and Guam). The Fleet Commanders in Chief are vested with direction and control of naval broadcasts, ship-shore, air-ground and other direct fleet support functions performed by the Naval Telecommunications System in their fleet areas. Direct liaison with the Commander, Naval Telecommunications Command in Washington, DC, is authorized to ensure proper coordination with other Navy users, other services, and the National Command Authority. The NAVCOMMSTA areas are shown in Figure 6-4.

The NAVCOMMSTAs transmit the fleet broadcasts, the primary method of delivering traffic to the forces afloat. The broadcasts are transmitted over a variety of frequencies to ensure receipt by all deployed forces. In the past, transmissions were mainly in the HF range, but the Navy is shifting rapidly to UHF communications via satellite relay. In time, the HF broadcast will be used primarily for redundancy purposes, except for the very few units which will not be fitted with satellite communications terminals. For example, in 1973, before the advent of naval satellite communications, the Navy operated 30 HF shore

stations with a total of about 1,600 transmitters. Today, the number has been reduced to 24 and 1,000 respectively, with further cuts likely. The Navy currently uses a network of four communications satellites, three leased GAPFILLERs (one each over the Atlantic, Pacific, and Indian Oceans), and one of the new Fleet Satellites (FLTSATs). Further FLTSATs will be launched as the useful life of the GAPFILLERs expires (see Chapter 9).

Navy ships and shore facilities can communicate with each other via any one of several communications means. Each deployed ship normally has several radio channels assigned to it for communicating with various echelons of the chain of command, both sea- and shore-based. Most of these channels will not be used continuously, but are available as needed. If normal Navy communication services are not available, all ships are authorized to use U.S. or foreign commercial radio stations.

An important factor contributing to the reliability of Navy communications is the flexibility of the Naval Telecommunications System to patch together systems of communication relays if a ship is unable to communicate with its normal correspondents ashore and afloat. This was a fairly common occurrence in the days before UHF satellite relays were available. HF communications are highly dependent on weather and upper atmosphere conditions, and it was not uncommon to have excellent communications with a station thousands of miles away and be unable to raise a station tens of miles away. Under those circumstances, a message would be relayed from one station to another until it finally reached its intended recipient.

Shipboard Radio Communications

Virtually all sea-going U.S. Navy ships can communicate with each other in a variety of frequency bands from HF to UHF. Submarines can also use lower frequencies (see "Submarine Communications") and certain flagships can communicate in SHF frequencies using the DSCS. Most ships copy the fleet broadcast in UHF, via teletypewriter, at over 100 words per minute. There is also a common fleet tactical UHF frequency on which any Navy unit may communicate with any other without prearrangement. This frequency, along with the fleet broadcast frequency, is one which must be guarded by all ships steaming independently. If two or more ships are operating in company, however, one may guard the fleet broadcast for other units.

UHF frequencies are used routinely between ships and/or aircraft operating in company as long as they are within line of sight of one another. For longer-range ship-to-ship or ship-to-aircraft communications, the ship will probably establish an HF link. These tactical HF or UHF links may be voice, or, if the ships/aircraft are NTDS-equipped, they may be digital links which print out on a teletypewriter or on a cathode ray tube. Also, manual Morse code may be used over HF links if desired. Encryption is available for some voice links and for most data links. Voice links may be "patched" from receivers in the ship's radio room to remote handsets on the bridge and in the Combat Information Center for ready access.

Most naval ship-shore and shore-ship messages are transmitted and received via high-speed radio teletype. A message is first put onto tape by an operator, who simply types the text on a keyboard which imprints appropriate coded signatures on tape. The tape is then run at high speed through the transmitter, which "reads" the tape and translates the coded signatures into electrical impulses. The receiver at the other end of the circuit routes the impulses to the teletypewriter system, where the message is decoded and printed out.

Each naval message is assigned a precedence and a classification. The precedence determines the relative importance of the message, and thus the order in which it will be transmitted. The precedences are, in ascending order, Routine, Priority, Immediate, and Flash. Flash precedence would be appropriate in cases where hostile action was in progress or imminent against a Navy ship or other U.S. activity, or in an area in which there was a vital U.S. interest. Immediate precedence is commonly used in the event of emergencies at sea or personnel injuries. Priority precedence is used most often for relatively significant administrative actions, for example, a ship needing repair parts for an important piece of equipment.

Messages are also classified according to their content, and are transmitted and distributed according to that classification. In order of ascending level of sensitivity, the message classifications are Unclassified, Confidential, Secret and Top Secret. Classification and precedence are not related, i.e., a message may have any combination of classification and precedence.

Tactical Data System Links

The principal means by which Navy ships and aircraft exchange tactical data is via the Naval Tactical Data System (NTDS). NTDS is a high speed, formatted data exchange system that not only provides the Officer in Tactical Command (OTC) with real-time strategic and tactical information from each of the platforms in his force, but also with the hardware to collate and display this information. The exchange of data is accomplished in a secure manner, in most cases through encryption of the transmitted data.

NTDS has three major communication routes or "links."

- Link 11. Link 11 is a two-way, real-time encrypted data link that operates in either the HF or UHF frequency ranges, providing good range and flexibility. Link 11-equipped platforms can constantly exchange tactical sensor data as well as weapon deployment and engagement status with one another. The key to Link 11 is the control memory and processing unit that permits virtually automatic, and secure, exchange of data.
- Link 14. Link 14 is a one-way, UHF or HF link from NTDS-equipped ships to other surface ships. Using Link 14, Link 11-equipped units can transmit encrypted data to ships lacking the complex central memory and processing equipment. This raw data is then transcribed manually into a form suitable for presentation to onboard commanders for possible action.
- Link 4A. Link 4A is a one-way data link used to control interceptor aircraft. NTDS surface ships and ATDS aircraft can control a suitably equipped interceptor aircraft via Link 4A, as well as provide vector information for the pilot to follow manually.

Submarine Communications

Because of the generally covert nature of submarine operations, submarines normally communicate in a "receive only" mode. There is a submarine broadcast in the VLF range, via special very high power transmitters, just as there is a fleet broadcast for the surface fleet. In order to receive the broadcast while

Figure 6-5. Submarines are the primary recipients of Very Low Frequency (VLF) broadcasts from stations such as the one above, located at Annapolis, Maryland. Although VLF stations require relatively large tracts of land, they are compact in comparison with the Navy's experimental Extremely Low Frequency (ELF) installation.

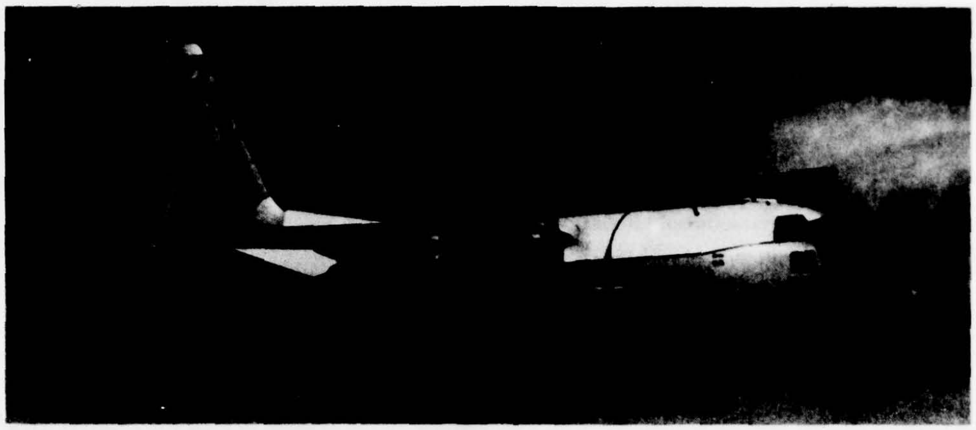

Figure 6-6. Specially configured EC-130G/Q TACAMO aircraft serve as airborne relay stations for strategic communications. They relay messages to submerged SSBNs by means of a retractable VLF antenna wire up to several miles long.

submerged, the submarine must trail an antenna wire on or near the surface of the water, or, tow a communications buoy slightly beneath the surface. Submarines are also capable of communicating in the other standard Navy frequency bands, but must raise an antenna above the water surface to do so.

These communications systems require the submarine to operate relatively near the surface and impose some limitations on both speed and maneuverability. Their use could conceivably reveal the presence of the submarine in some tactical situations. Because the nuclear-propelled ballistic missile submarines (SSBN) must be in constant communication with the National Command Authority (due to their strategic role), this operational limitation is accepted and they generally operate with an antenna wire or buoy deployed. The tactical missions of the attack submarines allow for greater flexibility and these submarines need not remain in continuous communication with shore-based commands.

The need to communicate with deployed SSBNs at all times has led to their being equipped with a variety of communications systems. The deployed SSBN force is served by the Minimum Essential Emergency Communications Network (MEECN), which links the strategic retaliatory forces (Strategic Air Command bombers and Navy SSBNs) to the NCA via a highly redundant communications system.

In addition to receiving the VLF broadcast transmitted directly by shore stations, patrolling SSBNs can also receive VLF communications relayed by specially configured Navy EC-130G/Q TACAMO aircraft. There are two squadrons of these aircraft, one in each fleet area. TACAMO EC-130s receive several redundant uplinks from ground- and air-based elements of the NCA in the VLF through UHF bands. They relay these communications to patrolling SSBNs at VLF frequencies using 10,000-35,000 foot trailing wire antennas.

To reduce the need for U.S. submarines to operate near the ocean surface while maintaining communications, the Navy has been developing an ELF communications program. ELF transmissions have the advantage of penetrating the water as much as 20 times deeper than current VLF emissions, enabling submarines to receive communications at greater operating depths than presently possible. Like VLF communications, ELF transmissions are essentially immune to atmospheric disturbances, either natural or caused by nuclear bursts. The major disadvantage of ELF is a very low data rate. Thus, the continued use of communications systems operating in the high frequency bands would be required to pass higher volume traffic. However, an ELF system would enable shore-based authorities to execute pre-planned emergency actions or to alert submarines that an important message was being sent through normal channels, thereby sparing submarines the necessity of operating near the surface unless it were absolutely necessary.

An ELF system broadcasts a signal by means of a buried antenna grid which might contain hundreds of miles of antenna cable. For the antenna grid to propagate the ELF signal effectively, it must be located

atop geologically "old" bedrock, which limits the number of possible sites for ELF systems. The focus of SANGUINE and SEAFARER, two Navy ELF programs whose funding has been terminated, was in the upper peninsula of Michigan, where geological conditions are optimum.

Visual Communications

Most visual communications systems in use today have been employed in much the same way for centuries. Their continued use is evidence of their utility, although their limitations, particularly concerning data rate, are severe and they are usually considered a secondary means of communication. Visual systems used today include flashing light, semaphore, flaghoist and pyrotechnics.

Flashing light employs a signal lamp with a moveable shutter over the lens. The shutter is opened and closed rapidly by hand, permitting messages to be sent within line of sight using Morse code. The method is slow but reliable both day and night in good weather. Its use can compromise the ship's location at night, however. To improve the security of flashing light, the Navy has deployed the NANCY system, which uses the infrared spectrum instead of visible light. NANCY emissions can only be seen through a special infrared viewer.

Semaphore is the sending of individual letters of the alphabet via the momentary positioning of two signal flags by a signalman. The position of the flags determines the letter or numeral. Semaphore is not commonly used in the fleet today.

Flaghoist involves the use of coded flags displayed prominently, usually on a hoist running up to a yardarm on the ship's mast. Each flag represents a letter, a numeral, or a designated special meaning. The meaning of the flaghoist is listed in a signal book, one for the NATO Allied navies, and a second for use by all ships at sea, the International Code of Signals. Flaghoist and flashing light are commonly used for close-in communications in the fleet. When entering or leaving a port, Navy ships normally display their international radio call signs in a flaghoist.

Pyrotechnics, especially flares of various kinds, have been used at sea for centuries, but today are employed more for signalling than for communicating because of the strictly limited-combination of displays possible. Their most common use today is as part of the survival equipment issued to aviators and placed in lifeboats.

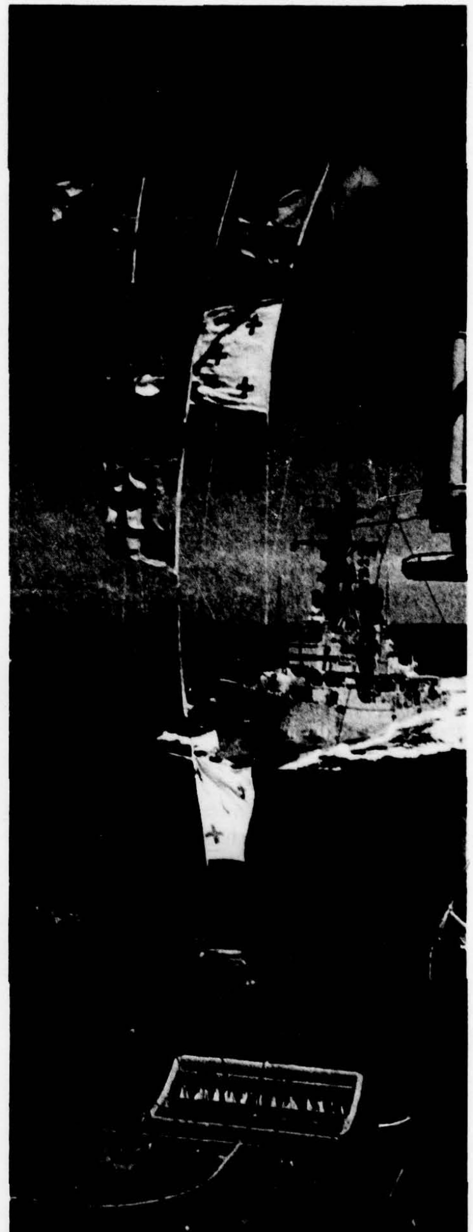

Figure 6-7. Simple visual signals, like this flag hoist, still have a place in modern naval communications, particularly for talking with nearby ships and for reducing tell-tale electronic emissions.

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As the foregoing description indicates, naval communications are highly complex and multi-faceted. The need to support diverse types of forces in situations ranging from normal peacetime operations to nuclear war calls for communications that are reliable, fast, and secure. The adverse environmental conditions that characterize at-sea operations make this objective all the more difficult to achieve. Nevertheless, modern navies have risen to the challenge, and, in doing so, have created communications systems that are among the most advanced and capable in existence. Continued attention to the problems and opportunities of effective communications will be necessary, not only to maintain present levels of effectiveness, but to supply the new systems, concepts, and doctrines that will assure continued effectiveness in the operational environment of the future.

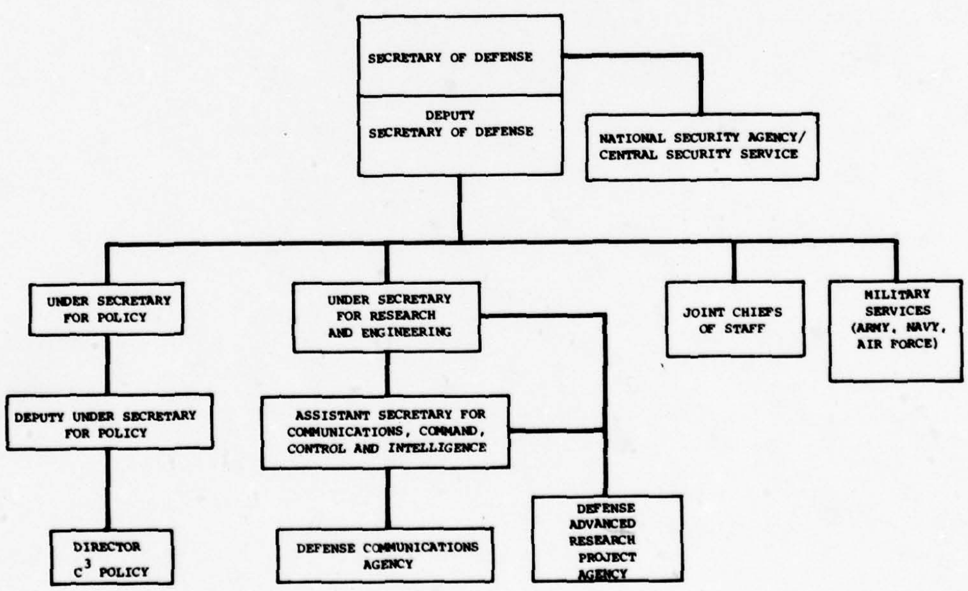

Figure 7-1.
Department of Defense C^3-Related Organizations.

7
SHORE SUPPORT ACTIVITIES

Shore support activities associated with U.S. Navy command, control, and communications have three major functions: (1) policy and planning; (2) research and development of new C^3 equipment, systems, and techniques; and (3) management of existing systems, including such vital functions as procurement, personnel training, and logistics support. Many different organizations are part of the shore establishment. Some are part of the Navy; others belong to the Department of Defense (DoD), where programs applicable to more than one service are coordinated. Still others are part of private industry, where much independent research and development is carried out. In this chapter, organizations at the Department of Defense level will be discussed first, followed by Navy organizations.

DEPARTMENT OF DEFENSE C^3-ORIENTED ORGANIZATIONS

The organization of C^3-related activities in the Department of Defense may be divided for conceptual purposes into three areas: policy-making (Under Secretary of Defense for Policy and his subordinates), consumers (Joint Chiefs of Staff and the military services), and management/development (Under Secretary for Research and Engineering and his subordinates). Figure 7-1 portrays the general relationships among DoD C^3 activities as of 1979.

The Under Secretary of Defense for Policy is the principal staff assistant to the Secretary of Defense in the policy areas of political-military affairs, intelligence analysis and collection, communications, command and control, and integration of departmental plans and policies with overall national security objectives. There is also a Deputy Under Secretary for Policy, who specifically examines and reviews C^3 requirements and, assisted by the Director of C^3 Policy, formulates and coordinates DoD C^3 policy.

The Under Secretary for Research and Engineering is responsible for all DoD weapons system acquisition, including research, development, test, and procurement. He provides for the coordinated resource and policy management of the closely related functions of telecommunications, command and control systems, and intelligence. He also supervises the Defense Advanced Research Projects Agency (DARPA), Defense Communications Agency, Defense Nuclear Agency, and Defense Mapping Agency.

A key subordinate of the Under Secretary for Research and Engineering is the Assistant Secretary for Communications, Command, Control, and Intelligence (C^3I). The Assistant Secretary for C^3I is the highest DoD official dealing primarily with C^3 programs. His responsibilities in this field include technology development, budgetary matters, and overall management. He exercises direct control over the Defense Communications Agency, and also serves as manager of the Telecommunications and Command and Control Program, which was established in 1970 to coordinate and consolidate the various communications systems operated by the military services.

The Defense Communications Agency (DCA) is the lead DoD agency for the operation and maintenance of the Defense Communications System (DCS), the long-haul, point-to-point communications system for all DoD organizations, including the Navy (see Chapter 6). In general, DCA operates only those portions of the DCS used primarily by the National Command Authority. The individual services operate those parts which are primarily service-oriented (for example, the Navy's shore-ship communications network) on behalf of the DCA.

Although it is under the control of the Assistant Secretary for C^3I and his superior, the Under Secretary for Research, the Defense Communications Agency also responds directly to the Chairman of the Joint Chiefs of Staff both on operational matters and on the communications requirements associated with their joint planning responsibilities.

The mission of DCA includes:

- performing systems engineering for the Defense Communications System, and ensuring that the DCS is operated and maintained to provide efficient, effective communications for the National Command Authority, Department of Defense, and other government agencies as directed
- providing system engineering and technical support to the National Military Command System and the Minimum Essential Emergency Communications Network, both elements of the communications system linking the strategic retaliatory forces and the National Command Authority
- providing engineering and technical support to the World Wide Military Command and Control System
- performing system architect functions for current and future military satellite communications systems
- providing analytical and automatic data processing support to the Joint Chiefs of Staff, Secretary of Defense, and other DoD components
- procuring leased communications circuits, services, facilities, and equipment for the DoD and, if authorized, other government agencies.

The management of the revolutionary, high-risk, high-payoff basic research and applied technology projects designated by the Secretary of Defense is the responsibility of the Defense Advanced Research Projects Agency. The objective of these programs -- many of which involve C^3 -- is to minimize the possibility of technological surprise and to develop major additions to national defense capabilities. Research and development projects are taken to the demonstration stage in order to assess feasibility, after which the project is turned over to the appropriate military departments.

Some of the C^3-related projects under DARPA auspices are:

- completion of the technology base for modern command and control by applying emerging computer science, communications, and information processing technologies
- provision of a testbed environment for evaluating alternative C^3 architectures and deriving empirical data for designing operational systems
- development of multi-destination, packet-switched communications technology, which enables radio networks to reconfigure themselves automatically according to the movement of radios in the field
- creation of new aids for crisis management by developing new information management-technology and improving man-machine interface
- development and demonstration of a natural-language interface to a distributed data base system to give users around the world access to large data bases via computer communications networks
- improvement of computer communications network security
- development of laser communications systems as a possible future alternative to current techniques.

DARPA is currently engaged in several C^3-related joint programs with the Navy including one with the Naval Ocean Systems Center (NOSC) and a second with the Navy and CINCPAC. DARPA and NOSC have jointly developed the Advanced Command and Control Architectural Testbed (ACCAT), a flexible design tool for determining the architecture and function of future (1985-1990) C^3 systems and for evaluating the technology upon which future systems will be built before making costly deployment decisions. The Navy/CINCPAC/DARPA project is called the Military Message Experimental Center, and is installed at CINCPAC headquarters in Hawaii. The objective is to evaluate secure interactive message communications systems in a military environment.

Another DoD agency dealing directly with C^3 is the National Security Agency/Central Security Service (NSA/CSS). The NSA/CSS has two primary missions, communications security and foreign intelligence. NSA was established by presidential directive in 1952 as a separate agency within DoD. At that time, the Secretary of Defense was designated the executive agent for the signals intelligence and communications security activities of the government. Since 1972, the communications security function has been performed by the CSS, which is headed by the Director, NSA/CSS. The Director has the authority to prescribe certain communications security principles, doctrines, and procedures for the U.S. government and to regulate certain communications in support of Agency missions. This communications security role gives NSA/CSS far-reaching authority in the day-to-day use of telecommunications in the Navy, the Department of Defense, and the government as a whole.

DEPARTMENT OF THE NAVY C^3-ORIENTED ORGANIZATIONS

Many organizations are involved in the shore support establishment for Navy C^3, and each contributes in some way to formulating C^3 policy, managing assets, and developing new equipment and procedures. There are many organizations involved because C^3 affects every part of the Navy: the various platforms of the operating forces, the command structure, the logistics support eatablishment. In spite of the resulting complexity, the degree of coordination between the various shore establishments responsible for C^3 policy, management, and development is high, and certain organizations have been established to ensure that the maximum in coordination and interoperability is achieved.

Activities Under the Secretary of the Navy

The Secretary of the Navy is responsible for policy, administration, and control of the Department of the Navy. Under him, two of the three Assistant Secretaries of the Navy are involved with C^3: the Assistant Secretary for Manpower, Reserve Affairs and Logistic and the Assistant Secretary for Research, Engineering and Systems.

The Assistant Secretary for Manpower, Reserve Affairs and Logistics has responsibilities which include all matters relating to Navy material, telecommunications, civilian and military manpower, real estate, and facilities. His office sets management policies and priorities in these areas at the broadest level. Elements of the Navy C^3 structure coming under his general authority would include the procurement of C^3 equipment, training of personnel to operate it, logistics support over the service life of the equipment, and construction of any shore facilities necessary to house or maintain it.

The Under Secretary for Research, Engineering and Systems is responsible for all matters relating to research, development, engineering, test, and evaluation efforts within the Navy. His broad authority thus extends over every Navy C^3 system before it is approved for procurement for the fleet.

The Assistant Secretary for Research, Engineering and Systems has delegated his authority for all C^3 matters to the Deputy Assistant Secretary for Command, Control, Communications and Intelligence (C^3I).

The Deputy Assistant Secretary, C^3I acts for the Assistant Secretary in providing policy guidance and direction in matters relating to the formulation, review, and execution of plans, policies, and programs relative to research, dvelopment, and acquisition of all Navy C^3 and intelligence systems. He is responsible under the Assistant Secretary for ensuring compliance with Secretary of Defense and Secretary of the Navy acquisition directives and guidelines. He serves as the interface with the Department of Defense on matters relating to C^3 and intelligence and represents the Secretary as required in liaison with other defense agencies and government organizations, industry, the academic community, and the Congress on all matters pertaining to command, control, communications, and intelligence.

Directly subordinate to the Assistant Secretary is the Office of Naval Research, which undertakes and coordinates scientific investigations of electronic devices and electromagnetic phenomena. More focused research activity from the point of view of Navy C^3 is conducted by the Naval Research Laboratory (NRL) in Washington, D.C. NRL conducts a broad-based multidisciplinary program of scientific research and advanced technological development directed toward new and improved materials, equipment, techniques, systems, and related operational procedures for the Navy. NRL emphasizes basic research areas such as satellite and secure communications, computer architecture, and communications intercept and jamming.

Activities Under the Chief of Naval Operations

The Chief of Naval Operations (CNO) is the senior military officer of the Department of the Navy. He is the principal naval advisor to the President and the Secretary of the Navy on the conduct of war, and the principal naval advisor and naval executive to the Secretary on the conduct of the activities of the Department of the Navy.

Elements of the Navy C^3 establishment that operate under the control of the CNO are shown in Figure 7-2. Within the immediate Office of the CNO (OPNAV), two directors have C^3 interests and responsibilities. These are the Director, Command and Control and Communications (C^3) Programs (OP-094) and the Director, Research, Development, Test and Evaluation (OP-098).

major operating areas.

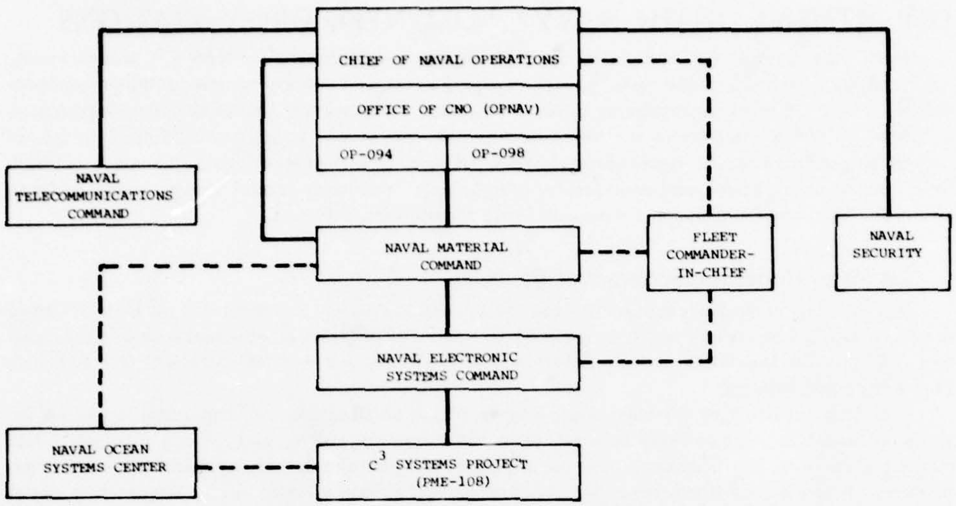

Figure 7-2.
C^3 Related Organizations Under the Chief of Naval Operations. (Dotted lines indicate liaison and coordination, solid lines indicate direct subordination.)

The Director, C^3 Programs exercises authority for the CNO over the planning and programming of Navy C^3 and cryptology. He is responsible for C^3 systems architecture, and serves as the interface between OPNAV and the Office of the Secretary of Defense, other services and agencies, and the Joint Chiefs of Staff on C^3, cryptologic, and WWMCCS matters. In general, he is responsible for the formulation of Navy C^3 policy subject to approval of the CNO and Secretary of the Navy. As a policy-making body, OP-094 is in constant contact with the fleet Commanders-in-Chief to determine operational requirements, and with the various research and management oriented C^3 organizations of the shore establishment. The Program Director is thus in the best position to match operational requirements with support assets, and to propose new initiatives to remedy current shortcomings.

The Director, RDT&E (OP-098), implements the responsibilities of the CNO and assists the Assistant Secretary for Research, Engineering and Systems with respect to coordination, integration, and direction of the Navy's RDT&E program, a portion of which involves C^3.

The Commander, Naval Telecommunications Command (NTC) also reports to the CNO, but unlike most OPNAV staff directors, he has line responsibility for the management of an operational command. The Commander, NTC, exercises direction and management control of assigned elements of the Naval Telecommunications System; serves as the Operations and Maintenance Manager of those portions of the Defense Communications System assigned to the Navy; acts as coordinating authority for the CNO in carrying out Department of the Navy responsibilities for telecommunications; and commands the Naval Telecommunications Command and other activities and resources as assigned by the CNO.

Until the late 1960s, overall direction of the Navy's communications systems came directly from OPNAV in the person of the Assistant CNO (Communications)/Director of Naval Communications. This officer served both as the CNO's principal communications advisor (as does the Director, C^3 Programs, today) and as the commander of the Navy's radio communications organization (Commander, NTC). These two functions are differentiated because of the increasing complexity and volume of naval communications; the introduction of new, more sophisticated, command and control techniques and philosophies; and the increasing necessity of ensuring the interoperability of new C^3 systems among the military services.

The Commander, NTC's most important operations and management responsibilities include:

- developing and establishing standards and operating procedures, in conjunction with the Fleet CINCs, to be used within the Naval Telecommunications System

munications between fixed shore installations.

- directing the efficient use of resources for fleet surface, air, and subsurface telecommunications under the Fleet Operational Telecommunications Program, in conjunction with the Fleet CINCs
- advising the CNO and Chief of Naval Education and Training on the adequacy of Navy C^3 training, and recommending improvements if required
- managing the cryptographic equipment program for the Navy, Marine Corps, and Coast Guard
- coordinating with the fleet CINCs and other elements of the Department of the Navy to ensure the compatibility of the various fleet tactical communications systems with the Naval Telecommunications System.

The Commander, Naval Security Group, also reports directly to the CNO, and is responsible for cryptologic and communications security programs in the Navy. He therefore has direct influence in the day-to-day operation of Navy communications systems at all levels.

Activities Under the Chief of Naval Material

The Chief of Naval Material and selected subordinates are responsible for coordinating the C^3 RDT&E and procurement process to ensure that the C^3 systems being designed and developed by different Navy organizations for various fleet uses will be compatible with each other and with systems currently in the fleet, when they finally attain service status. The mission of the Naval Material Command (NAVMAT) is to serve as the single, integrated material support agency within the Navy with central responsibility and accountability for the total system and material support needs of the Navy. This support includes the development, acquisition, procurement, maintenance, alteration, and overhaul of Navy ships, aircraft, submarines, weapons, and weapons systems. The Chief of Naval Material also provides direct staff assistance to the Secretary of the Navy on matters pertaining to contracting, procurement, production, RDT&E, and Navy laboratories. Thus, the Chief of Naval Material has widespread duties and responsibilities concerning all aspects of Navy C^3.

The Chief of Naval Material has assigned the Commander, Naval Electronic Systems Command (NAVELEX) material support responsibility for platform-to-platform (as opposed to intra-platform) C^3 systems. The Commander, NAVELEX is responsible for the research, development, test, evaluation, procurement, logistic support and other material functions related to shore-based and certain common-use airborne and shipboard electronics, including C^3, electronic warfare, navigation, countermeasures, and certain other systems. NAVELEX is the Navy's central authority on electronic standards, technology, and compatibility. It is the Chief of Naval Material's final authority for C^3 systems and equipment, provides NAVMAT interface with OPNAV, the other NAVMAT systems commanders, the Defense Communications Agency, and other services and agencies for all C^3 functions within the Naval Material Command.

The Chief of Naval Material promulgates the Navy's C^3 Master List, which contains all the Navy's ongoing C^3 programs. He then assigns Principal Development Authority (PDA) for each program among the NAVMAT program managers and the project managers in the systems commands. The selection of a PDA for a particular Master List item is based primarily on how directly the item falls under the purview of one of the program managers or systems commands. For example, a new tactical data display system aboard a destroyer would probably be assigned to the Naval Sea Systems Command. A new system which primarily involved a ship-to-aircraft data link would likely be assigned to NAVELEX, since that command has principal authority for platform-to-platform C^3 projects. Clearly, any given C^3 Master List item could easily have both intra-platform and inter-platform aspects, and this factor will tend to determine the degree of development authority vested in NAVELEX.

Each item on the C^3 Master List is under the coordination and integration authority of the Project Manager, Command, Control, and Communications Systems Project (PME-108), regardless of which NAVMAT organization is assigned as PDA. The C^3 Systems Project is a component element of NAVELEX, operating under and reporting to the Commander, NAVELEX. The responsibilities of the C^3 Systems Project Manager include:

- correlating total Navy C^3 requirements into an integrated Naval Material Command C^3 Master Plan
- developing and maintaining the C^3 Master List
- providing management guidance, direction, and information to the Systems Commanders and designated Project Managers to effect a fully integrated and coordinated C^3 program in the Naval Material Command

- providing, under the Commander, NAVELEX the primary interface with OPNAV, the Systems Commanders, Defense Communications Agency, and other Services and agencies for all C^3 functions.

The C^3 Systems Project has a variety of operating relationships with other NAVMAT activities, Navy organizations, services, and agencies. It furnishes the Chief of Naval Education and Training the information needed to provide instructors for operation, maintenance, and overhaul training for the approved CNO Training Plan. The Project is *authorized* direct contact with the CNO Program Coordinators for C^3 projects in establishing, implementing and reporting on C^3 efforts in accordance with the Navy Programming Manual. It also is authorized to have direct contact with cognizant Army and Air Force elements on all matters concerning JTIDS and TRI-TAC (see Chapter 9). Other major Navy organizations with which PME-108 maintains routine contact include the Naval Ocean Systems Center, Naval Ship Engineering Center, Naval Ship Research and Development Center, Naval Surface Weapons Center, Naval Undersea Systems Center, Naval Air Development Center, and Naval Research Laboratory.

The Naval Ocean Systems Center (NOSC)

The principal naval laboratory center engaged in C^3 RDT&E is the *Naval Ocean Systems Center* located in San Diego, California. Its mission is to serve as the principal Navy research, development, test, and evaluation center for C^3, ocean surveillance, surface and air launched undersea weapons systems, and supporting technologies. The major sponsors for the RDT&E work it performs are the Director of Naval Laboratories; Commander, Naval Electronic Systems Command; and Commander, Naval Sea Systems Command.

NOSC was established in 1977 through the merger of the Naval Electronics Laboratory Center and the Naval Undersea Center. It is a full-spectrum RDT&E center, from planning and intelligence inputs

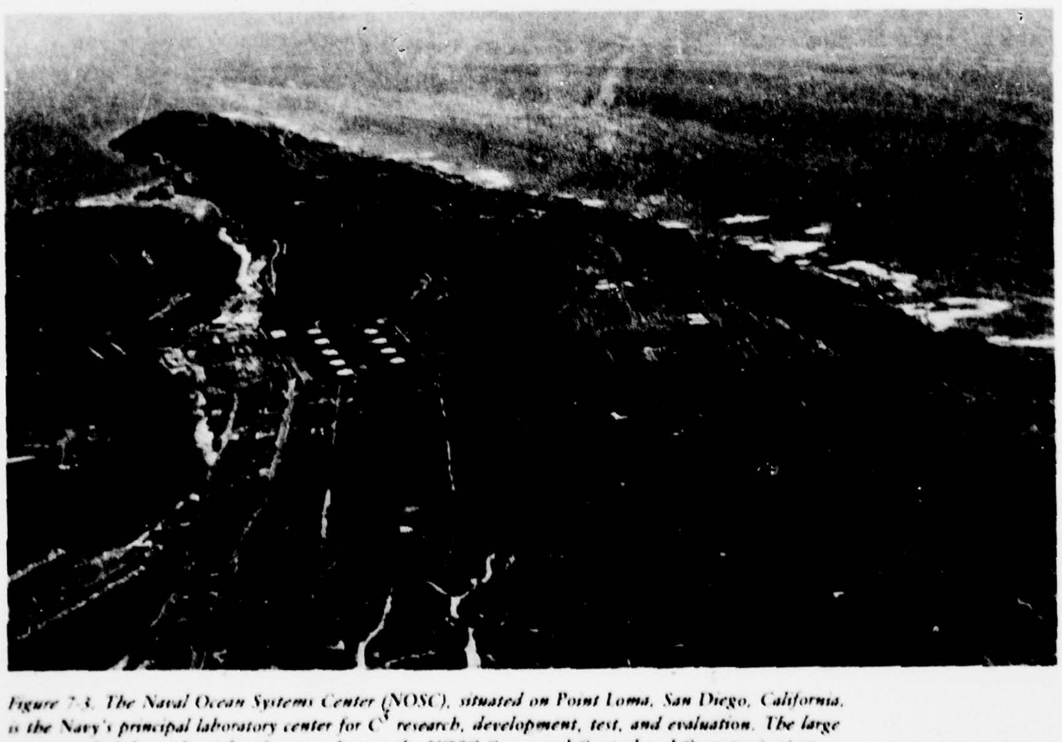

Figure 7-3. The Naval Ocean Systems Center (NOSC), situated on Point Loma, San Diego, California, is the Navy's principal laboratory center for C^3 research, development, test, and evaluation. The large structure slightly to the right of center, houses the NOSC Command Control and Communications Directorate and a number of related activities. The C^3 Systems Integration Test and Evaluation (C^3SITE) location is above and farther to the right, near Point Loma's Pacific shore.
(NOSC Photograph 1875-10-73A)

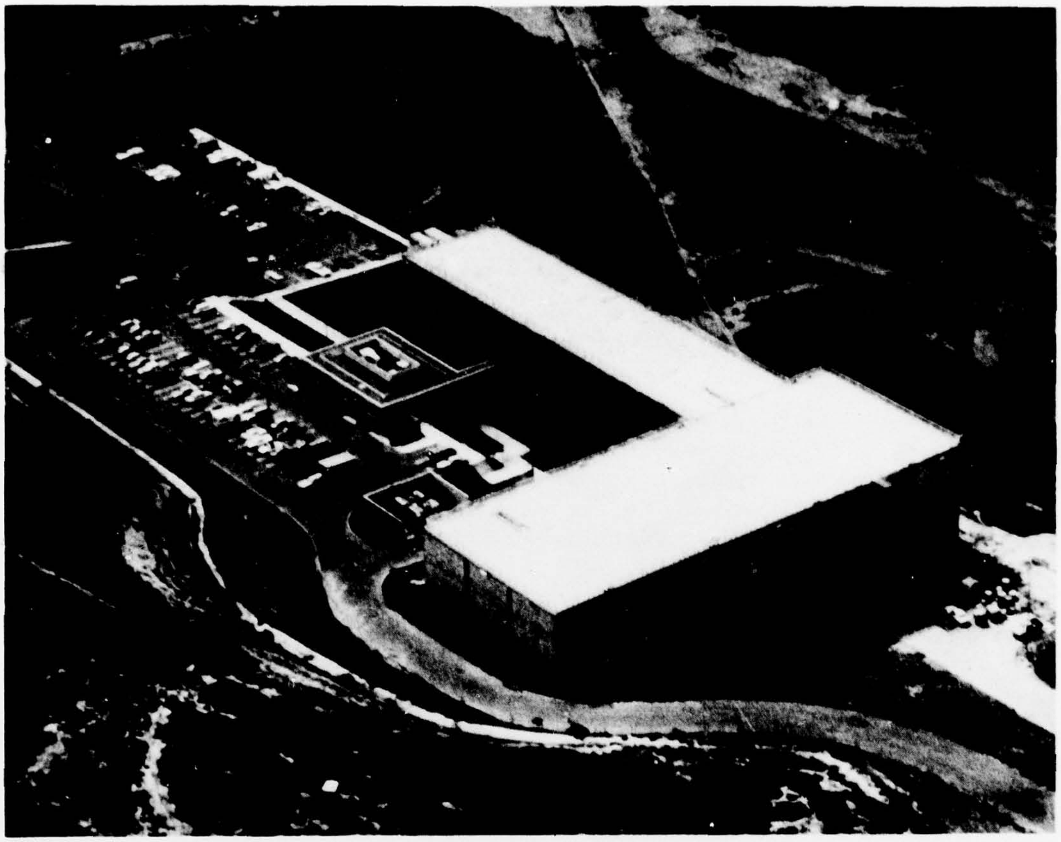

Figure 7-4. The C^3 Systems Integration Test and Evaluation (C^3 SITE) facility provides a controlled, electromagnetically secure environment for integrating and testing complete electronic C^3 systems. (NOSC Photograph 112-1-78A)

through the command, control and decision-making process via communications, to the ultimate response in terms of weapons and electronic warfare. In addition to RDT&E, NOSC pursues an extensive in-house and Navy program of systems analysis and evaluation to provide support for in-service systems and direct assistance to the Fleet. NOSC has a staff of about 2,600 employees, and a military allowance of about 360 officers and enlisted personnel.

The principal NOSC facility for C^3 RDT&E is the C^3 System Integration Test and Evaluation (C^3 SITE) facility, which provides for development, integration, and testing of complete electronic systems in a controlled environment, both electromagnetically and physically secure.

The NOSC element with primary responsibilites for C^3 RDT&E is the Command, Control and Communications Directorate (Code 08). The Directorate plans, directs, and conducts a comprehensive program of C^3 RDT&E which includes system architecture, networking techniques, components, software, and hardware required to support development of C^3 systems. He also provides and manages complete C^3 system design from concept formulation through integrated logistic support, and is responsible for the management of the C^3 SITE.

NOSC's Systems Analysis Office (Code 16) is also involved in C^3. The C^3 and Ocean Surveillance Analysis Group (Code 162) analyzes the effectiveness of alternative system configurations and operating procedures; develops functional specifications for systems; plans and directs demonstrations of system feasibility and performance; and provides analytical support to other center activities as needed. Major C^3 RDT&E efforts at NOSC in the late 1970s have included:

- theoretical and experimental research and development of efficient blue-green lasers for use in underwater applications
- Tactical C^3 Intelligence Land-Based Test Site to ensure system inter-operability
- tri-service JTIDS
- low-cost Link 11, providing real-time communications capability for Naval Tactical Data System
- VERDIN/enhanced VERDIN program, for improving submarine communications
- submarine communications terminal for a survivable satellite communications system
- message processing system for the Minimum Essential Emergency Communications Network (MEECN)
- advanced C^3 Architectural Testbed for evaluating concepts and technology.

• • •

Although designed to stay at sea for long periods, modern U.S. naval forces nevertheless depend on close coordination with support activities ashore. This is particularly true of the U. S. Navy's C^3 capability, which depends on shore activities not only for the development and support of specific systems and components, but for the planning and guidance that make it an effective part of the overall U. S. C^3 organization. Extensive shore support is essential in order to realize the full potential of today's complex and sophisticated C^3 assets.

8
PERSONNEL

The people who operate and support the U.S. Navy's command, control, and communications network come from a wide variety of backgrounds. Some have become familiar with the field through Navy training programs and through experience in Navy operations. Others have begun their careers with degrees in related disciplines such as electrical engineering, management, or systems analysis.

The C^3 community afloat includes the tactical commanders, the operators who man combat direction and communication systems, and the staff and maintenance personnel who support them. Most C^3 personnel afloat are concerned with ship and force operations and equipment maintenance. When rotated ashore, many of these same people perform in billets related to the planning, development, and management of C^3 systems.

OFFICER CAREERS

Junior officers normally begin their professional association with C^3 by serving in communications or in the shipboard Combat Information Center (CIC). The Atlantic and Pacific Fleets have training programs in these areas that are available to newly commissioned junior officers. Training usually takes about eight weeks. Communications officers manage communications in virtually all Navy ships and most shore stations. In most ships, they also share watchkeeping duties and must qualify in their warfare specialty in addition to developing their knowledge of communications procedures and equipment.

CIC officers are responsible for the efficient functioning of the CIC, the nerve center of Navy warships. The CIC processes and displays tactical information from all sources to assist decision-making by the Commanding Officer. In combat, the ship is "fought" from the CIC.

Communications and CIC billets are not the only way in which junior officers first become involved in C^3. The first tour of duty ashore can also provide an opportunity for deeper study and understanding of C^3. The notional career pattern for a Surface Warfare Officer shown in Figure 8-1 lists assignment to the Naval Postgraduate School as a possibility in both the first and second shore tours. Thus, it is possible for an officer to earn a master's degree in a C^3-related area by the time he or she had completed four years as a lieutenant. Subsequent shore tours would then be spent in appropriate C^3 billets.

Opportunities for work in C^3 are similar for junior officers in all warfare specialties. However, these opportunities tend to become more restricted in the higher ranks. Most naval officers are designated as specialists in certain fields. Unrestricted line officers become specialists in Surface, Submarine, Air, or Special Warfare. Restricted line officers specialize in more limited mission areas such as intelligence, while staff corps officers attain specialization in support organizations such as the Supply Corps. Navy C^3 billets above the level of lieutenant additionally require special technical expertise identified by a subspecialty designation. All officers can obtain subspecialty designations through education or experience, and their subspecialty then becomes a secondary professional development field in addition to the major specialty. This section will address C^3 subspecialties primarily available to the unrestricted line officers, who occupy most C^3-related billets.

Within the Office of the Chief of Naval Operations, the Deputy Chief of Naval Operations (Manpower) identifies C^3 subspecialty requirements in consultation with the Director, Command and Control and Communications Programs (OP-94). The Director, Naval Education and Training (OP-099) establishes and controls subspecialty education programs based on these requirements, and the Chief of Naval Personnel selects and assigns appropriate personnel.

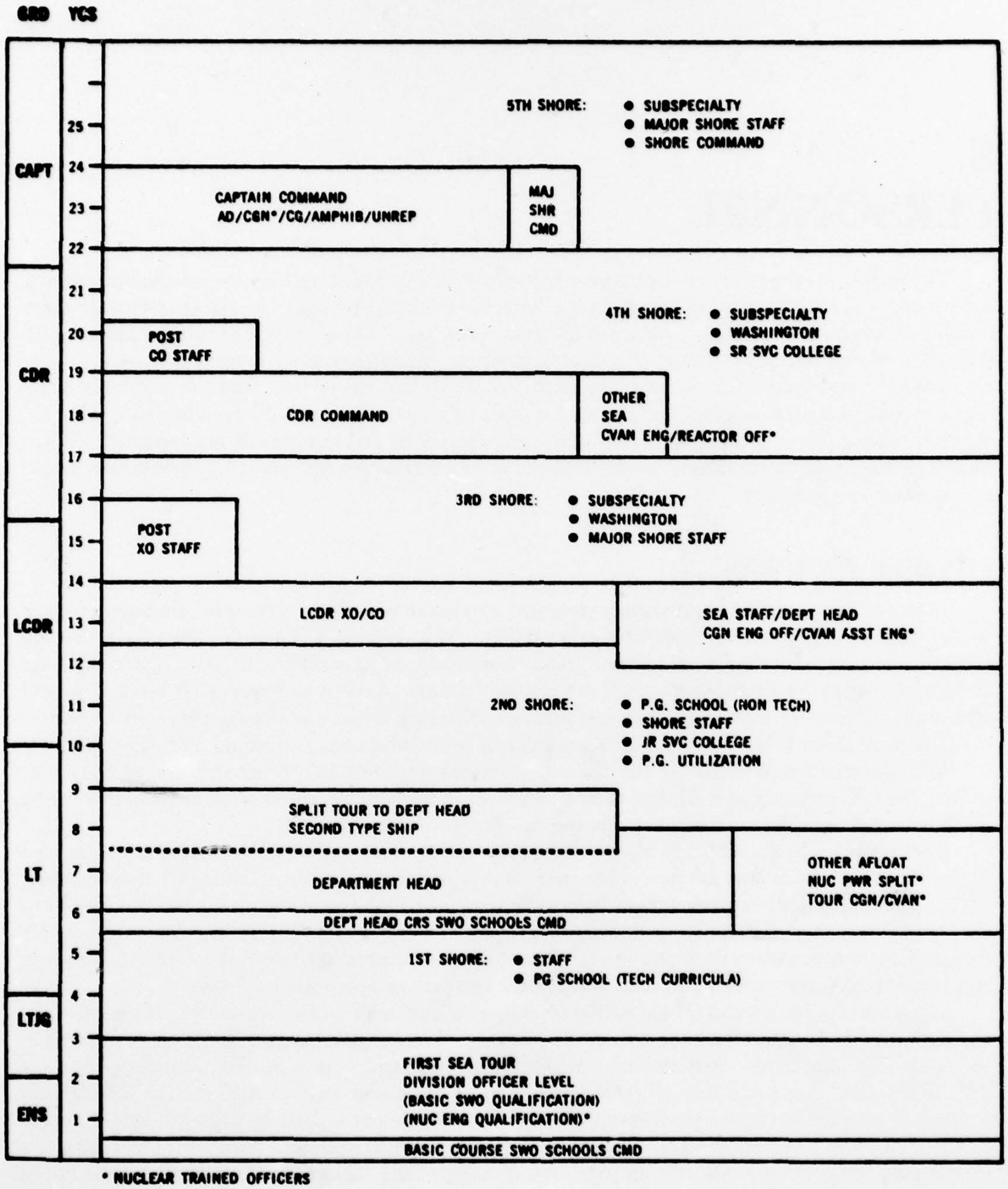

Figure 8-1.
Surface Warfare Officer Professional Development Path.

Each subspecialty is "sponsored" by a headquarters activity that employs large numbers of subspecialty-coded officers. The subspecialty sponsors advise the various subspecialty requirements, personnel, and education coordinators of their specific needs. The headquarters activities with the most expertise in a given subspecialty area are known as subspecialty consultants, and are responsible for stating skill requirements and evaluating the degree to which education and training meet these requirements and the needs of the sponsors. The consultants also recommend necessary changes in subspecialty training

C^3 SPONSORS	EDUCATIONAL/SKILL FIELD		CONSULTANTS
	TITLE	CODE	
	1. COMMUNICATIONS		CNO (OP-941)
			Naval Security Group
			Naval Electronic Systems Command
	General	5080	Naval Telecommunications Command
	Engineering	5081	
CNO (OP-094)			
	Systems Technology	5082	
CNO (OP-02, OP-03, OP-05, OP-095)			
Naval Security Group	2. COMPUTER TECHNOLOGY		CNO (OP-942)
Naval Telecommunications Command			Naval Security Group
Naval Electronic Systems Command			Naval Telecommunications Command
	General	5090	Naval Material Command
Naval Oceanographic Office			Office of Naval Research
	Computer Science	5091	Naval Electronic Systems Command
	Computer Systems	5095	
	Combat Direction Systems	5096	

Figure 8-2.
Navy C^3- Related Subspecialty Structure.

or education. Thus the primary employers of subspecialty-coded officers and the command with the most related expertise are directly involved in ensuring the technical expertise and qualifications of officers in their respective fields.

The first two numerals of a subspecialty code denote background experience in one of the eight broad functional fields. The second two numerals represent a somewhat narrower skill field, while the letter suffix indicates the level of the skill noted in the second set of numerals. Figure 8-2 shows the structure of the subspecialty coding system for the broad area of C^3 (50xx-series subspecialty codes).

Officers may acquire a subspecialty code either through education at a civilian institution or at the Naval Postgraduate School, or by serving in a billet specifically identified as providing a significant level of C^3 experience. Subspecialty selection boards, convened every two years by the Chief of Naval Personnel, review subspecialists from lieutenant commander through captain.

NAVAL POSTGRADUATE SCHOOL

The Naval Postgraduate School, Monterey, California, offers several courses leading to assignment of a C^3-related subspecialty code. The recently established Joint C^3 Curriculum (#365), which includes courses in computer science, operations research, administrative science, electrical engineering, and national security affairs, teaches the principles of joint C^3 systems, with particular emphasis on integrating technological advances with operational requirements. This curriculum, open to officers of all services, offers a master of science degree, and requires one to one-and-one-half years depending upon the student's qualifications.

Figure 8-3. The Naval Postgraduate School, Monterey, California, has recently established a joint C^3 Curriculum that includes courses in computer science, operations research, administrative science, and other related disciplines.

Two interdisciplinary curricula leading to a master of science degree address the growing military role of automatic data processing. The Computer Systems Curriculum (#367) integrates mathematics, accounting, economics, computer science, behavioral science, and management techniques into an understanding of the technical management of large computer centers. The Computer Science Curriculum (#368) equips the student to design and evaluate computer systems and to provide technical guidance in military applications ranging from basic data processing to sophisticated tactical systems. This curriculum integrates mathematics, probability, statistics, operations research, and electronics in addition to computer hardware and software theory and application.

A third set of curricula concentrates on the communications function. The Communications Engineering Curriculum (#600) provides a broad basic engineering background, and leads to advanced studies in the communications engineering of Navy and DoD C^3 systems. This curriculum offers a master of science degree, with some superior students taking their degrees in electrical engineering, which requires additional course work and a thesis of greater depth. The Telecommunications Systems Curriculum (#620) is designed to provide instruction in the management of new communications applications and major communications installations afloat and ashore. It provides comprehensive study in systems management, plus selected technical courses specially prepared for non-engineers.

ENLISTED PERSONNEL

Enlisted personnel participate in all phases of Navy C^3, operating and maintaining a wide variety of complex equipment. The principal C^3-related ratings are:

- Radioman (RM). Radiomen operate the Navy's radio communications systems. They transmit and receive messages; operate teletypewriters and radios; and coordinate and operate automated communications networks, satellite data links, and the full spectrum of voice and teletype circuits.
- Electronics Technician (ET). Electronics Technicians maintain, calibrate, and repair all electronic C^3 equipment in ships and at shore stations.

- Operations Specialist (OS). Operations Specialists man shipboard radar, navigation, and communications equipment in the CIC and other C^3 spaces. They detect, track, and identify ships, aircraft, and missiles; maintain plots of contacts; and communicate with other ships and with aircraft.
- Data Systems Technician (DS). DS ratings maintain, adjust, and repair digital computers, video processors, tape units, digital display equipment, data link terminal sets and related equipment.
- Signalman (SM). Signalmen employ visual signals (flashing light, flaghoist, semaphore) and voice radio to communicate with other ships. They also assist ship navigators.

As a rule, enlisted personnel entering a C^3-related rating pass directly from recruit training to a Class-A school, which provides a basic level of training in a specific rating specialty. Class-A schools vary in length from a few weeks to six months or longer. Some graduates go directly to fleet or shore assignments; others proceed to Class-C schools, which train personnel in the operation and maintenance of specific pieces of equipment. These courses are generally short, from one to a few weeks in duration, and are also available on an as-required basis to enlisted personnel already serving at duty stations. For example, a ship that acquires a new ECM receiver may send one or two enlisted personnel to a Class-C school to learn how to operate and repair it. Class-C schools are conducted at the various Fleet Training Centers on the U.S. east and west coasts.

The Chief of Naval Technical Training, under the Chief of Naval Education and Training in Pensacola, Florida, manages most training for naval enlisted personnel in the C^3-related ratings. He is directly responsible for course content and structure, for matching the proper number and type of courses and instructors with fleet personnel requirements, and for keeping pace with changing equipment configurations.

Overall policy guidance for C^3-related training is provided from the CNO staff level by the Director of Naval Education and Training (OP-099), in close consultation with the Director, Command and

Figure 8-4. An instructor explains the functions of radio gear at a Radioman "A" school under the Service School Command, San Diego, California. Enlisted personnel entering any C^3-related rating generally pass directly from recruit training to a Class-A school such as this one.

Control and Communications Programs (OP-094). The Chief of Naval Personnel is responsible for making a sufficient number of appropriately qualified personnel available for training and instructor duty.

The training which a typical Radioman might undergo in his career exemplifies C^3-related training for enlisted personnel. Following recruit training, the RM "striker" attends a few weeks of the Basic Electricity and Electronics course, which teaches the principles of electricity and electronics. The Radioman Class-A School begins with a common eight week course in communications security, message formatting, administrative functions, and typewriting. The school then splits into two "tracks," a two-and-one-half week preparation for shipboard duty, or a one-and-one-half week preparation for duty at a shore station. Some Radiomen go on to attend one or more functional courses at Class-C schools before reporting to their new duty stations. These courses include manual morse code, teletypewriter repair, and satellite communications. At some point later in his career, a long-term Navy Radioman may also attend a Class-B School, which focuses on the managerial and administrative skills required of senior enlisted personnel.

Billets for C^3-related ratings are available both ashore and at sea. The Navy attempts to keep the amount of time spent at sea and on shore tours approximately equal over the length of a serviceman's career. Personnel in some ratings, however, can expect to spend more of their careers assigned to fleet units because their job specialties are directly associated with shipboard equipment and duties.

CIVILIAN PERSONNEL

Although most of the people who operate the DoD and Navy C^3 systems on a day-to-day basis are military personnel, civilians play an important role in developing and supporting this vital capability. Generally, the role of civilian personnel is to provide program and policy guidance, and to supply technical expertise for developing new systems and maintaining those already in existence.

The Secretary of Defense and his civilian subordinates provide policy and program guidance for DoD-wide C^3 systems, in accordance with the principle of civilian control of the military. The Secretary of Defense also supplies a certain amount of guidance for C^3 programs and activities controlled by the individual services. Most of the civilian personnel who formulate C^3 policy at the DoD level are concentrated in the offices of the Assistant Secretary for C^3I, the Under Secretary for Policy, and the Defense Communications Agency. The Office of the Secretary of the Navy provides similar policy and program guidance for U.S. Navy C^3, with detailed C^3 policy formulation falling primarily to the Deputy Secretary of the Navy for C^3I and his staff.

Civilian employees of the U.S. government and private industry provide a great deal of the technical support for U.S. C^3 systems. Their contribution is particularly crucial in the area of research and development, both to improve existing capabilities and to provide new ones. The Defense Advanced Research Projects Agency is primarily staffed by civilians. Major centers for C^3 research within the services, such as the Naval Ocean Systems Center, also have large staffs of civilian experts, as do development and acquisition activities within the Naval Material Command. Both the military and civilian C^3 staffs within the government work closely with civilian experts in private industry to develop, maintain, and improve U.S. C^3 assets.

Traditionally, electrical engineering was the predominant specialty for civilians working in the field of C^3. Electrical engineers design, develop, test, and evaluate electronic equipment, specify its uses, and write the necessary performance requirements and maintenance schedules. Their traditional predominance reflects early emphasis on the communications function and on the development of hardware to perform specific and limited tasks. Although the numbers of electrical engineers working in C^3 continues to increase as the entire field expands, their relative share of civilian C^3 jobs has tended to decline.

Other specialties have taken a greater share of C^3-related civilian jobs. The role of aerospace engineers in C^3 development has expanded as integration of aircraft and missiles with other military assets becomes closer and more intricate. Similarly, the challenges of integration have augmented the roles of industrial engineers and other operations researchers, who specialize in applying mathematical concepts to organizational problems and in determining the most cost-effective ways to utilize major factors such as people, equipment, and supplies. These specialists, like electrical and aerospace engineers, hold at least a bachelor of science degree in their field, and frequently have advanced degrees as well.

The most outstanding growth in C^3-related civilian expertise has come in the field of automatic data processing. Designing and modifying highly automated C^3 systems is the responsibility of systems analysts, who discuss system requirements with military specialists, analyze the problems involved, and employ techniques such as sampling and mathematical modeling to devise new solutions. They then translate these results into "hardware" specifications for the electrical engineers and "software" specifications for computer programmmers.

A great many systems analysts hold advanced degrees, and they frequently have a background in the physical sciences, mathematics, or engineering. A knowledge of a related scientific or engineering discipline can be helpful when applying systems analysis techniques to specific C^3 problems. A growing number of systems analysts, however, have degrees in computer science, information science, or data processing. Whatever the specific degree, systems analysis invariably requires a thorough knowledge of the computer languages involved in military and scientific endeavors.

The work of civilian data processing specialists goes beyond the somewhat abstract efforts of systems analysis. Civilian programmers employed by DoD, by the military services, and by defense contractors take the charts, diagrams, and written specifications developed by the systems analysts and determine the correct program procedures to achieve the desired results. Although some programs can be written in a matter of days, C^3 programs, which frequently employ complex mathematical equations and call for many data files, may require months or even years to prepare. Once the program has been written, programmers and systems analysts collaborate to test and perfect it, a process known as "debugging" the program.

Although there are no universally accepted training requirements for computer programmers, most are college graduates. The technical aspects of defense C^3 systems often call for backgrounds in mathematics, engineering, or the physical sciences.

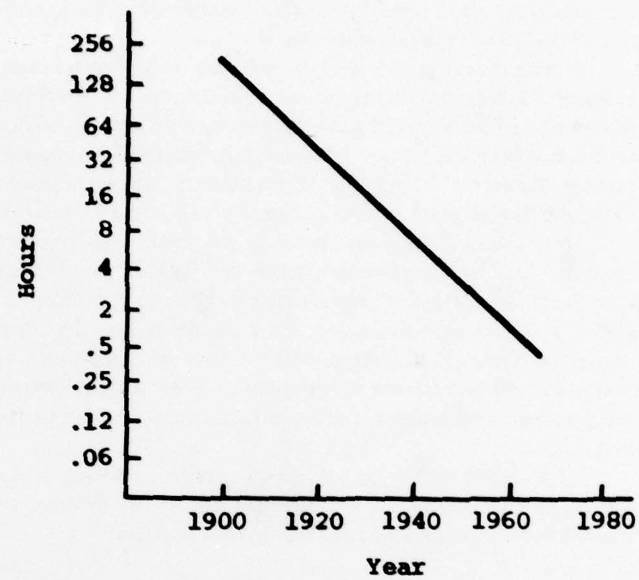

Figure 9-1.
Weapon Deployment to a Nominal Range of 2000 Nautical Miles.

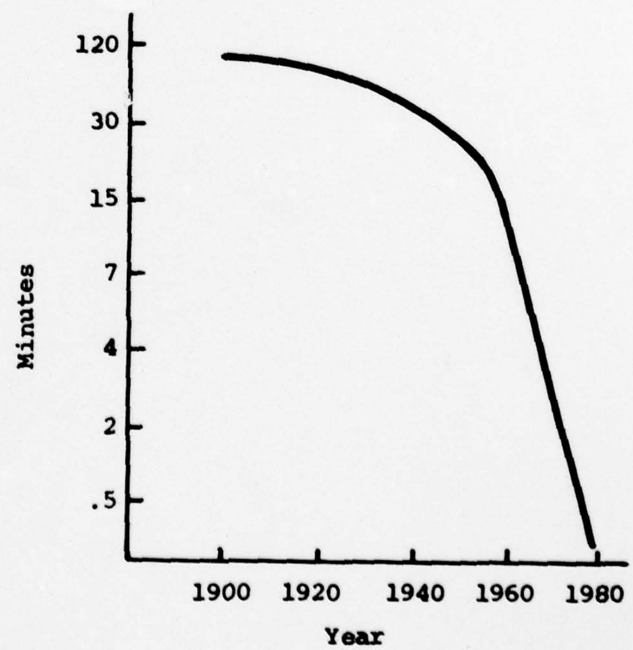

Figure 9-2.
Nominal Defensive Reaction Times.

9
FUTURE TRENDS

CHANGING ENVIRONMENT

Historically, command, control, and communications have tended to improve in response to changes in warfare technology. The naval operating environment in the last quarter of the twentieth century can be expected to be one of constant change, as rival powers develop and deploy increasingly complex and capable systems.

The trend in threat development, as indicated by Figure 9-1, has long favored greater mobility, speed, and firepower. In response, the defense reaction times shown in Figure 9-2 have tended to become shorter. Although surface ship speeds may have remained relatively constant since World War II, the mobility and speed of aircraft and submerged submarines have improved remarkably. This trend will probably continue with future aircraft and submarines. Because of the improved platform mobility of potential enemies, the friendly units that first detect an approaching threat may be less capable of countering it, or even assessing it correctly, without external assistance. Therefore, widely dispersed surveillance systems will need rapid access to processing facilities capable of gleaning essential information from the mass of available threat data, and then passing the essential information to the proper defensive system.

For example, a U.S. nuclear-propelled submarine in direct support of a task force may detect a rapidly approaching submarine, but may not be in position to attack it. The U.S. submarine will have to pass its contact report to a command center that can assess the information and assign the target to a specific aircraft or surface ship. This must be accomplished before the enemy submarine has time to reach the most effective launch range, when, in the case of a cruise missile attack, a completely different set of defense weapons (anti-air rather than anti-submarine) would have to come into play.

The extension of sensor ranges and the increasing rate at which platforms can exchange sensor data are two other changes that will greatly affect the operational environment of the future. In some cases, these changes will favor the offense, which will target the defending force from well beyond the horizon. In some cases (such as longer-range submarine detections with towed acoustic arrays) improved sensor range and data handoff will favor the defense. But, whatever its implications, greater sensor capability will invariably call for more rapid and extensive C^3 for all the forces involved.

The growing range and speed of delivery systems will continue to multiply the effect of improved platform mobility, as it has in the past. Perhaps the most dramatic example of rapidly evolving delivery systems is the cruise missile. The trend in its development has led from the large, subsonic missiles of the 1950s to missiles that can travel several times the speed of sound, approach targets from very high or extremely low altitudes, and maneuver to evade anti-missile defense. Steady improvements in guidance, airframe, and propulsion contribute to the increasing firepower of attacking forces.

One counter to growing enemy capabilities, in addition to similar improvements by defensive systems, is dispersal. On sea, as on land, the long-standing trend has been toward increased distance between cooperating units. Dispersal permits defense in depth for high value units, giving the defending force more time to react after detecting the threat. Dispersal, however, is less of an advantage when it reduces overall force effectiveness. A slow or inadequate reaction by defensive systems loses the benefit of greater standoff ranges. C^3 systems must therefore improve to handle greater dispersal.

Navy C^3 must also react to a higher degree of system diversification and subsystem specialization. For example, whereas a fast aircraft carrier in World War II needed only attack and fighter aircraft, the much larger carriers of today must also operate specialized reconnaissance, electronic warfare, early warning, and anti-submarine aircraft. The capabilities and tasks of other ship types have also diversified. The

submarine is a good example. Torpedoes and, to a lesser extent, mines were their principal weapons during World War II, but today's submarines may also carry anti-submarine standoff weapons and cruise or ballistic missiles. System diversification multiplies the number of data sources, the volume of data, and the number of subsystems demanding information and guidance. Keeping abreast of this demand calls for more extensive data processing and command automation, which themselves require additional coordination.

Because the tempo of modern conflict is bound to increase in the future, C^3 systems must become more precise, as well as more rapid. Not very long ago, an aircraft carrier's combat air patrol could make a successful intercept with only approximate range, bearing and course information supplied by voice link. Against today's aircraft and missiles, far more precise information is needed. In addition to complicating factors such as electronic countermeasures, high speed targets simply tend to generate data at a faster rate than targets traveling at a lower speed. In future conflicts, interceptors will use target information displayed on "heads up" digital cockpit displays. Operators in remote command facilities will also "fly" fighter aircraft directly to the best intercept point by means of computer-to-computer data links.

Finally, the introduction of improved command, control, and communications will itself serve to change the operating environment, and will call for further improvements. Part of the impetus for current efforts to upgrade U.S. Navy C^3 capabilities is the existence of an impressive Soviet C^3 capability, demonstrated during the 1975 OKEAN exercises. The Soviet Navy's ability to launch a single, well-coordinated strike against several widely separated U.S. forces obviously calls for better coordination of U.S. fleet defense. More sophisticated C^3 therefore joins the list of key military parameters that will determine the C^3 requirements of the future. C^3 systems must respond to these expanding parameters with appropriate improvements in data exchange, multi-source correlation, analysis, assessment, decision-assistance, and force coordination. Failure to provide the necessary C^3 support for new military capabilities has always proven dangerous, but it is especially so in an era when limited conflict can rapidly escalate to intercontinental exchanges and mass destruction.

DIGITAL REVOLUTION

Most of tomorrow's command, control, and communications system will rely on digital technology. The rapid substitution of digital for analog systems, and the increasing capability of the digital systems themselves, constitute the most important trend in C^3 equipment. Since the introduction of digital NTDS in the early 1960s, the proportion of digital C^3 equipment in the U.S. Navy has increased steadily. Most remaining analog equipment will be phased out over the next few years. Programs are also underway to replace earlier generations of digital equipment with more up-to-date systems.

Digital C^3 systems have several advantages over analog, the first of which is superior performance. Digital communications have more capacity per channel. A digital link can handle voice, teletype, facsimile, and computer data in a single transmission, whereas separate transmissions are usually necessary with an analog link. Digital signals can be regenerated many times without degrading the quality of the communications link. With an analog signal, noise and distortion tend to be cumulative.

Digital command and control computer systems can handle much larger volumes of data with greater flexibility than analog systems. This is largely a matter of processing capacity. For example, with today's technology, a pocket calculator can integrate a greater number of points than tons of analog hardware from the 1950s. Large-Scale Integration (LSI) -- the fitting of large numbers of miniaturized circuits onto a single computer panel -- has progressed rapidly in the past few years, giving each new generation of digital computers a much larger processing capacity per unit of volume.

The development of capable small computers has, in turn, given rise to "federated" systems involving multiple computer installations. Instead of a large, central installation processing virtually all data for a given system, much data processing takes place at smaller installations, which exchange information directly with one another. The central installation, which no longer participates to the same degree in basic processing, can take on the "executive" function of monitoring and supervising the flow of data throughout the system.

The terms "distributed data processing" and "interactive computers" are used to denote this new method of dealing with modern information requirements. As each element in a distributed system pro-

vides more data processing for its own particular function, overall system capacity increases, and demand on the central facility decreases. Decentralization can also make the system more survivable. If one element of the system is degraded, the central installation may allocate part of its function to another element. If the central installation itself is damaged, one of the lesser elements may take part of its coordinating function. Thus, distributed data processing systems tend to degrade "gracefully," i.e., with less chance of a sudden catastrophic failure.

The command and control benefits of distributed systems are obvious, but even all-digital C^3 systems have certain inherent limitations, which will become apparent as the growing volume of data processing encounters, at least temporarily, the physical limits of current LSI technology.

Distributed systems can extend this limit somewhat by dividing the data processing demand among a larger number of federated processing elements, but the need for overall system coordination limits the number of elements that can be added. Even if advanced data transmission systems can speed the flow of data between computers, the system will have to dedicate more and more of its data processing capacity to coordinating this flow. The growing attention to executive functions will detract from the system's ability to perform its primary mission.

These inherent limitations should not obscure the fact that all-digital C^3 systems will be far more effective than the present mix of digital and analog hardware systems and will also be relatively less expensive. The proliferation of available LSI packages makes digital hardware more than competitive with comparable analog equipment. As a rule, digital hardware costs less to maintain, and its superior capability may reduce the operating cost for a given level of effort. Finally, the advent of all-digital systems will do away with today's costly and cumbersome interfaces between digital and analog elements.

COMMUNICATIONS TRENDS

A marked improvement in signal-to-noise ratio is one of the most important technological trends in modern communications. The signal-to-noise ratio is the proportion of useful signal, as opposed to meaningless electromagnetic noise, that can be distinguished at the receiver. The potential benefits of increasing the signal-to-noise ratio include better reception in the face of heavy interference (e.g., jamming), longer transmission ranges, and higher data rates.

Two customary methods of improving the signal-to-noise ratio are increasing transmission power across the board and concentrating a given level of power in a smaller range of frequencies. Both methods raise the energy content of the transmitted signal in relation to that of natural and other man-made emissions in the surrounding environment. However, the degree to which transmitted power can be increased or concentrated is subject to a number of limitations, including practical limitations on the size and sophistication of transmission equipment. Moreover, an enemy can counter such increases simply by augmenting the power or precision of his own jamming equipment.

Such limitations would tend to curtail further improvement in signal-to-noise ratios were it not for another significant trend in modern communications technology: the declining importance of power, as opposed to processing. Automated signal processing systems can "package" the information content of a transmission so that it becomes recognizable only to another, similarly programmed processor at the receiving station. This processor can then isolate the specially packaged signal, and reject unrelated emissions from other sources. In fact, it can seek out and isolate the true signal even when other emissions are significantly stronger.

Advances in signal processing make it much more difficult for an enemy to block key communications. Jamming power must be increased by an order of magnitude in order to overcome the processor's rejection of unrelated signals. On the other hand, confusing the processor is difficult without a detailed knowledge of how it is programmed. Finally, the ability of signal processing to recover the correct signal even in the presence of powerful interference, makes it possible to "hide" the signal in natural or man-made noise, leaving the enemy totally unaware of its existence.

The growing effectiveness of individual communications modes will not, however, decrease the need for redundancy. The Navy will continue to invest heavily in redundant communications systems to overcome the effects of potential variations in upper atmospheric conditions, equipment malfunctions, or enemy actions. The first problem can ordinarily be circumvented by switching to equipment less suscep-

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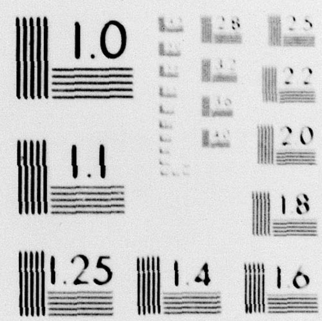
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tible to atmospheric changes, e.g., equipment operating in the UHF or LF/VLF frequency bands. Malfunctions can be reduced by improving equipment reliability and maintenance procedures. However, no piece of equipment can be relied upon to function perfectly at all times, so some backup equipment will always be required.

Enemy actions that could interrupt, or degrade the Navy Command and Control System include:

- Simple jamming of satellite UHF uplinks and more sophisticated jamming of SHF uplinks (i.e., those used by the DSCS satellites)
- Degradation of communications by nuclear bursts in the atmosphere which affect both the propagating medium and the communications equipment itself
- Long-range jamming and direction finding activities aimed at long-haul HF communications
- Pinpointing radiation sources for UHF or SHF uplinks with enemy satellites that could provide preliminary information to higher-resolution systems
- Direct attack on U.S. communications satellites.

The Navy is currently engaged in a number of programs designed to increase the survivability, flexibility, speed, and reliability of its communications, while at the same time reducing the size, weight, and complexity of required equipment. The most important efforts involve shifting from HF to UHF (satellite-relayed) fleet communications, improving security through increased emphasis on communications encryption, and joint projects designed to improve communications interoperability and establish commonality throughout the armed forces.

A key element of future naval communications will be the Fleet Satellite Communications (FLTSATCOM) System. Four satellites, each with 23 operating channels, will be placed in geosynchronous orbit (i.e., an orbit which keeps the satellite over a fixed point on the earth's surface). The Navy will share these satellites with the Air Force, and will utilize 10 channels: one for the fleet broadcast, and nine to relay communications between aircraft, ships, submarines, and ground stations. FLTSATCOM will improve Navy communications by (1) relaying much more Navy traffic than the three leased GAPFILLER satellites currently in operation; (2) providing better security than current HF and UHF systems; and (3) covering virtually the entire surface of the earth, except for extreme polar regions. The first FLTSATCOM satellite, with a design life of five years, was launched in early 1978.

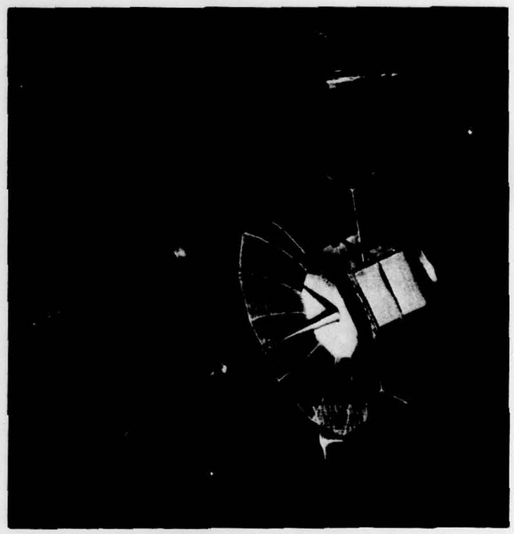

Figure 9-3. The Navy's Fleet Satellite Communications (FLTSATCOM) System employs joint Navy / Air Force relay satellites such as the one above to carry fleet broadcasts and priority two-way communications. Reliability, security, long range, and high data rates assure that satellites will play an increasing role in U.S. Navy C³.

The Navy is also undertaking a major effort to encrypt as much communications traffic as possible, thereby minimizing its usefulness as a source of intelligence for potential adversaries. Security for the Navy's HF voice links is especially limited at present, but secure voice systems now entering the fleet will soon provide encryption for HF, UHF, and satellite voice links.

ELECTRO-OPTICAL SYSTEMS

Optical C^3 is as old as naval warfare itself. For thousands of years, navies have used flags, lights and other visual signals to communicate orders and tactical information. The manual plots used to maneuver fleets of sailing ships were actually primitive optical command and control "displays." The first systems that combined optics and electricity were signal lights and automatic semaphores invented during the late

1800s. However, radio frequency (RF) communications, which promised more reliable performance at much longer ranges, supplanted visual signals for most purposes by the end of World War I.

Electro-optical development shifted from communications to display technology. The development of radar in the late 1930s called for some means to make the radar returns comprehensible to a human operator. Since human beings comprehend physical relationships most readily in an optical format, a variety of electro-optical radar repeaters were manufactured. Of these, the Plan Position Indicator (PPI), which presents radar echoes relative to the radar platform at the center of a radarscope, provided the most useful format for assessing tactical situations. PPI scopes proliferated rapidly during and after World War II, and the sheer volume of radar data they made available began to overwhelm human operators.

NTDS helped overcome the information glut by wedding controllable EO displays to electronic computers. The basic display was still a radarscope, but the operator could now manipulate radar returns either directly or by means of computer-supplied geometric and alphanumeric symbols. NTDS transformed simple sensor displays into complex tools for data manipulation.

Current trends in command and control technology favor more complex display capability. While some existing display systems combine analog and digital technologies, future systems will be completely digital. Small modular displays will meet the data presentation needs of a wide variety of C^3 systems. Major command and control installations will be completely automated with flexible large screen displays replacing the manual wall plots and status boards in use at present. Both large and small display systems will have an improved ability to interact with one another, reproducing entire situations, borrowing specific information, or synthesizing an overall picture from diverse pieces of borrowed information.

Driven by extensive computer installations, tomorrow's large screen displays will not be as dependent as today's command and control plots on late-arriving reports from the operational forces. By direct interaction, much of the data that appears at one location will be instantly available at other locations as well. For major command centers ashore, this will include data already analyzed and displayed by lower level command nodes.

In addition to providing sophisticated display systems, electro-optical technologies have also found new applications in the field of communications. Fiberoptics, the transmission of light impulses through transparent fibers, is one such technology. Optical fibers can carry more information at greater speed than metal cables. The light transmissions that they carry are less vulnerable to interception and nuclear effects. The small diameter and light weight of optical fibers make them ideal for ship and aircraft internal communications, where growing message traffic is making the weight and volume of metal cables increasingly prohibitive. Although many technical problems must be overcome before fiberoptics can be applied to long-range cable and landline communications, many shorter-range applications are feasible with current technology.

Another EO technology with great communications potential is the laser. Laser transmissions may be channeled through optical fibers, or beamed directly from transmitter to receiver. Unlike light from natural sources, which consists of many different frequencies and is subject to rapid attenuation, laser light forms a coherent beam at a specific frequency. This beam is highly directional and suffers little attenuation loss over distance.

Direct laser links analogous to current radio links have several potential advantages for point-to-point communications. Light frequencies are at least 10,000 times higher than the highest radio frequencies. Since the potential data rate of a signal tends to increase with its frequency, the theoretical transmission capacity of a laser beam is very high. For example, a single beam could theoretically carry all current traffic between the east and west coasts of the United States. The narrowness of the laser beam is another advantage for point-to-point communications. Even at high frequencies, RF antennas must be fairly large in order to produce a beam only a few degrees wide, and even the best beam-forming antennas produce side lobes pointing outward at an angle on either side of the main lobe. Since laser beams have essentially no sidelobes, enemy intercept or jamming equipment can only exploit or degrade a laser transmission when situated within the main beam. The very narrowness of a laser beam makes this very difficult to accomplish.

Despite these advantages, several technical obstacles limit the development of direct laser links. One significant obstacle is interference from smoke, clouds, and other phenomena that tend to attenuate natural light. Future advances in laser technology may overcome this difficulty, but the precise directionality of laser beams will continue to restrict their use to point-to-point communications. Fleet

broadcasts and other wide-area requirements will continue to be met by radio frequency transmissions, which can propagate in all directions, or at least in a wide arc from the transmitter.

Thus, it is unlikely that lasers will eclipse radio to the same extent that radio eclipsed earlier EO signalling devices. On the contrary, a mix of systems will probably develop, with each system performing the functions best suited to its unique characteristics. In this context, lasers appear ideally suited for providing line-of-sight tactical links with good security and a high data rate. Satellite and ground relay systems, like those now used for microwave frequencies, could also permit lasers to provide secure, high-volume, links between specific stations separated by great distances.

TIME DIVISION

Automatic data processing has made naval forces much more effective, but data transmission requirements have severely strained available internal and external communications. While new technologies such as fiberoptics and lasers can help ease the data exchange burden they may not be sufficient by themselves to handle the tremendous flow of real-time information in modern operations. Faced with the task of using available channels more effectively, C^3 researchers have developed the concept of time division. This concept is equally applicable to the data flow within a single command and control installation, or to communications among the diverse platforms in a major operation.

The basic concept of time division is simple. When two or more transmitters use the same channel, they cannot transmit at the same time without interfering with one another. This is equally true whether the channel consists of a single assigned radio frequency, a series of coordinated "frequency hops" through a wide RF spectrum, or a data transmission line between two computers. More than one station cannot transmit on a single channel without some form of time division.

Two drivers talking on a Citizen's Band (CB) channel employ a rudimentary form of time division. When one driver has completed the message he wishes to send, he signals the other driver to begin transmitting, and then turns off his transmitter. The second driver, in turn, sends his message, after which he signals the first driver to start transmitting again. This informal procedure gives each driver exclusive access to the channel for the necessary amount of time. However, as citizen's band users are well aware, informal time division procedures tend to break down when several people want to talk on the same channel. Assigning people to different channels is not a solution in highly populated areas, where the number of prospective talkers far exceeds the number of CB channels.

Although the "data burst" messages sent by computers transmit information many times faster than the human voice, the same problem of channel availability affects data transmissions. The proliferation of automated data processing means that many computers have to "talk" to one another over a limited number of channels. Fortunately, automatic data processing systems can divide time with much greater precision and speed than human beings. Time division systems now being developed will enable a large number of stations to exchange information on a single net.

Transmission time on a given channel is divided into a large number of time slots. A master station can then assign time slots to other stations in the net according to their transmitting needs. The master station sends regular signals at the beginning of each time slot so that all other stations can synchronize transmission and reception. A participating station can transmit only on the time slot assigned to it, but within that period it can broadcast without interruption.

The time division network goes through each of the allotted time slots in sequence, then repeats the process again and again. As the sequence progresses, each station "listens" automatically for designator codes indicating classes of messages that may be of particular interest. For example, fighter aircraft may listen for codes identifying air threat information, messages from other fighters, ground control transmissions and transmissions by airborne warning and control aircraft. On the other hand, fighters would ignore messages pertaining to gunfire support, anti-submarine warfare, and other matters that do not concern them. Thus, each station retrieves only information related to its particular function.

The complete series of time slots is known as the "data bus," since it picks up data at each succeeding station and delivers that data at the proper destinations. Figure 9-4 illustrates the data bus concept. The time slots themselves are measured in small fractions of seconds, which is more than enough time for a digital system to transmit a significant amount of data in brief "bursts," or "pulses." In fact,

a typical time slot consists of several segments: first, a synchronization burst from the master station; then, one or more data packets from the sending station; and, finally, a brief "guard period" of silence before the next synchronization burst.

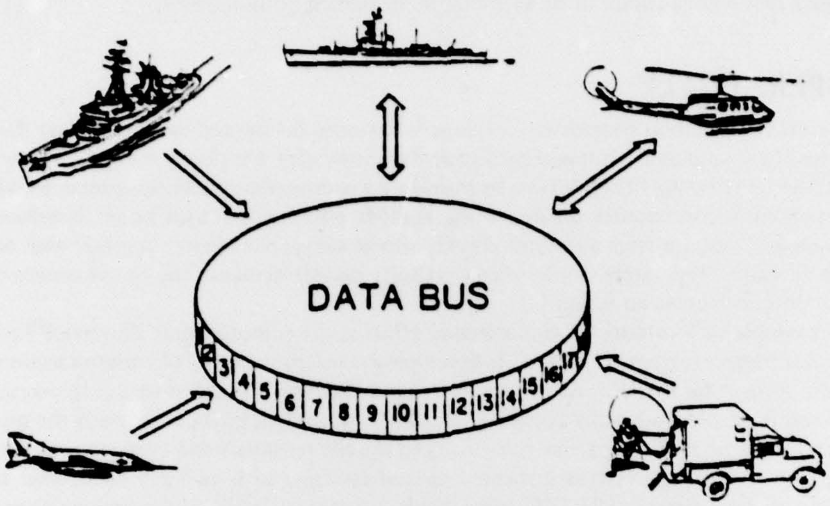

Figure 9-4.
Data Bus Concept

The data packets that make up the actual messages are analogous to the standard modular containers used for shipping freight. The data in each of these "containers" is treated as a single unit during transmission between stations. Each data packet carries an address code in addition to its information content. It may also carry an "error correction" code, i.e., one that provides sufficient information about the nature of the packet's contents so that the receiver can identify the correct message errors.

One simple method of error correction coding is to give each data packet a number indicating its position in the message as a whole. Suppose, for example, that a station transmits an uncoded message, repeating it once for clarity. If both the original message and the repetition arrive at their destination in a garbled state due to interference or transmission error, the receiving station would have no way to reconstruct the original text. However, if the original message consisted of three packets coded one through three, and if packet number two were missing from the first message and packet number three from the repetition, then the receiving station could identify and replace the missing packets. Or, if packet two were absent from both messages, the receiving station could request that the sender re-transmit the exact data needed to complete the original text. Since the required packet would carry its own address and sequence information, the sending station could simply insert it randomly in the next available time slot.

The use of very brief, standardized data packets is ideally suited to the newly-developed spread-spectrum, or frequency-skipping methods of secure, jam-resistant communications. A spread-spectrum signal consists of small message fragments sent at discrete, randomly-chosen frequencies throughout a relatively large frequency band. Data packets are ready-made for this technique. Not only do they lend themselves to discrete transmission in random order, but they have a built-in capability to correct the sort of transmission errors that are bound to crop up when numerous units are rapidly separated and reassembled.

The most important benefit of time division, however, is speed. Only a time division system carrying large numbers of data bursts in a short period can provide the rapid, coherent and threat-resistant response needed to conduct modern naval warfare. Finally, the redundancy implicit in such a system, in which each unit "talks" directly with numerous other units, ensures that battle damage will not lead to a

sharp decline in total force coordination. Graceful rather than catastrophic degradation could be possible despite the damage caused by high-intensity combat. A number of units in the system will have the capacity to assume the synchronization functions of a damaged master station. Damage to any individual station will therefore have only a marginal effect on system coordination, and even less effect on the amount of data that will continue to be available to all participating stations.

INTEROPERABILITY

As real-time coordination systems are developed, the need for interoperability among diverse forces becomes increasingly apparent. Interoperability and commonality are closely related. While commonality concentrates on reducing life cycle costs by providing a common family of equipment for all potential users, interoperability concentrates on improving combat effectiveness with better interfaces between equipment systems. Systems from a common family almost always have better interface with one another than systems developed separately, while interoperability usually demands the use of common elements at least at the interface between systems.

A good example of a current C^3 commonality effort is the common-user Tri-service Tactical (TRI-TAC) communications program. TRI-TAC is developing a common family of communications terminal and control equipment for the U.S. Army, Air Force, and Marines. Designed for use in overseas theaters of operation and in amphibious objective areas, TRI-TAC equipment includes not only the usual array of land-based and airborne tactical systems, but advanced mobile terminals and even long-range, time division satellite nets. Although certain dedicated tactical systems, such as Army small unit radios, will remain outside of the program, TRI-TAC will provide a common family of communications systems to satisfy most future Army, Air Force, and Marine Corps requirements.

SHORE-BASED COMMAND CENTERS

The advent of real-time communications with very high data rates, good security, and resistance to enemy interference has given new impetus to another important C^3 trend -- the tendency toward shore-based command and control. Like most command and control trends, this is not a recent development. But the technological developments of recent years have tended to serve as a catalyst, speeding up trends that would otherwise proceed at a more leisurely pace.

Prior to World War II, the Commander-in-Chief U.S. Fleet (CINCUS) flew his flag in a battleship. During the war, a single Washington-based officer served both as CINCUS and as Chief of Naval Operations. The new commander of the Pacific Fleet, Admiral Chester Nimitz, also carried out his duties at a shore-based headquarters, an unprecedented step for the commander of major U.S. naval operating forces. Nimitz's decision to take full advantage of modern, shore-based communications facilities bore fruit in superior U.S. force coordination during the decisive Battle of Midway.

Today, the commanders-in-chief of both the Atlantic and Pacific Fleets control their forces from shore, as do the commanders of the Second and Third Fleets. Although commanders of the forward-deployed Sixth and Seventh Fleets still fly their flags in specially equipped flagships, the trend toward shore-based command has resulted in their having extensive shore-based headquarters as well.

There are many reasons for this trend. Given a suitable level of real-time operational data available at a number of possible locations, most senior commanders will choose that location which offers the least distraction and is least vulnerable to disruption by the enemy. Shore installations free the commander from the extraneous noise and motion of the shipboard environment. In a conventional or limited war, they tend to be less vulnerable to enemy attack, and less likely to be put completely out of action if they are attacked. Thus, the commander ashore is often in a better position to exercise calm judgment based on careful assessments of the overall situation.

Obviously, if the level of information ashore and afloat were equivalent, a commander might well prefer the shore base. Such a preference will be strengthened in the future as advanced C^3 systems increase the level of information available ashore. The shore-based command center will be in much closer contact with surveillance and intelligence organizations that provide timely data on theater-wide developments. Compared to the constrained spaces aboard ship, the shore location offers virtually

Figure 9-5. The pace of missile-age combat poses a constant challenge to U.S. Navy command, control, and communications. Future naval forces will require increasingly capable C^3 systems if the Navy is to carry out its mission of defending U.S. interests on the oceans of the world.

unlimited volume for data processing to shift and correlate incoming data and give the decision-maker an accurate picture of the operational situation. Finally, communications facilities ashore are more redundant and reliable than those available even in a large naval combatant. Good communications ensure continuous, close contact with commanders on the scene.

COMMAND AUTOMATION

The pace of missile-age combat has led to more and more command and control automation for the forces actually engaged. Automation has progressed from automated plotting to automated threat indicators and decision-aids, and, finally, to the fully automated response mode of the new Aegis anti-air warfare system. When set to this mode, Aegis can take defensive action without any human intervention whatsoever, provided it recognizes certain pre-programmed threat criteria. As a matter of policy, human operators retain the ability to override the fully-automatic mode of Aegis, but the speed at which such decisions must be made in a high-threat situation leaves little time for human authority to intervene. By the very nature of the situation, new weapon systems such as Aegis must assume some of the lower-level decision-making functions traditionally associated with command and control. Only in this way can a commander ensure that his force will respond sufficiently rapidly during an attack.

As tactical responses become increasingly pre-programmed, the need for real-time command and control will shift upward to higher and more distant command echelons. The movement of naval resources over broad areas of the world's oceans will call for fewer decision-making delays as rival commanders seek to place their forces so as to make the best use of standoff ranges and automated systems. As in the days of battle lines and signal flags, the decisions of high level commanders will once again have an immediate and direct effect on operations, but the modern naval leader will exercise his command from an elaborate shore-based C^3 installation far from the battle area and connected to subordinate commanders by an array of advanced communications systems. This is the form in which the ancient art of naval command, control, and communications will reach the twenty-first century.